Henry C. Morel
Elmira
N.Y.

June 1872.

Yours truly
Dr Lewis Feuchtwanger

Heliographic Engraving Co.

A

HAND-BOOK ON SILEX,

EMBRACED IN

THREE PRACTICAL TREATISES:

I. ON SOLUBLE GLASS,

AND ALL ITS APPLICATIONS IN THE ARTS.

II. ON GLASS MAKING,

IN ALL ITS DETAILS.

III. A GUIDE FOR SOAP MAKING,

THE MANUFACTURE OF ALL SOAPS AND THEIR MANIPULATIONS.

CONTAINING

Thousands of Formulæ for Rendering Wood and Timber Fire and Dry Rot Proof, Silicifying Stones, Mortars, Concrete and Hydraulic Lime, White Washes, Paints and Cements, and how to Protect Wooden Shingles, Pavements, Rail-Road Sleepers, &c., &c.

By Dr. LEWIS FEUCHTWANGER,

CHEMIST AND MINERALOGIST.

New-York:

PUBLISHED BY L. & J. W. FEUCHTWANGER,

No. 55 Cedar Street.

1871.

JOHN W. AMERMAN, PRINTER,
No. 47 Cedar Street, N. Y.

INTRODUCTORY.

The first edition of the "Practical Treatise on Soluble Glass" being entirely exhausted, and the demand for the same daily increasing, have obliged the author to issue a new book, under the name of "A Hand-book on Silex," which is to embrace three separate treatises: 1. That on *Soluble Glass*, with all the latest applications in the arts, and for wood and stone. 2. The art of glass making in all its details. 3. The soap maker's guide for the production of soaps of every grade, such as family, toilet and silicated. The Author has bestowed particular attention on this work, having been encouraged by many flattering testimonials of approval by the Press and the public at large. He has introduced a great many improvements gathered from his own experiments, and published in many periodicals of the country, and which form at the present moment a very important branch of domestic industry. The soluble glass has, of late, become paramount in the arts, as many trades cannot dispense with it in their pursuits, and more so since the great conflagration of the City of Chicago, which took place on the 9th and 10th of October, where one-fifth of it was laid waste and destroyed; all the public buildings, churches, court-house, the principal business houses, and many wooden-roofed houses inhabited by poor people. This disaster has aroused in the minds of many men, and journalists in particular, the question whether or not such a catastrophe, by resorting to more

precautions in the construction of buildings could not be, in future, either entirely avoided, or conflagrations of any magnitude be stayed in the sudden progress of the fiery element. Well-informed men have so expressed their belief in letters to the Author, that the steeples of high buildings caught from the sparks flying in all directions from the contagion, and could with ease have been saved by a judicious management. The editor of the Scientific American of November 11th makes the following pertinent remarks in his leader respecting the great fire, which we copy here with alacrity, for they coincide entirely with the Author's ideas, and they inspire the hope that all the newspapers in the United States may take due notice of such valuable hints thrown out, and copy them in their local papers, so that all their readers may profit thereby, and follow out such precautions which this journal recommends, and whereby, at trifling expense and trouble, millions of dollars worth of property can be saved to owners and insurance companies.

He speaks of suitable building material in the following article:

"Recent events have turned the attention of thoughtful people to a consideration of the question of building material for large towns. It no longer appears proper to permit indiscriminate constructions, where the safety of a whole community may be endangered. We have, in large cities, superintendents of buildings, but they generally confine their attention to the question of security against falling, and not to the character of the building material, excepting in so far as wooden structures may be prohibited in certain districts. There would now appear to be cogent reasons why commissioners should be appointed to secure greater precautions than the mere question of wood and iron. A mixed commission, composed of builders, architects, underwriters, firemen and

scientific experts, could be appointed to study the whole subject and report thereon to the government. The commission could very properly decide upon the survey of streets, and the width, the kind of pavement and flagging to be used. They could lay down water pipes and establish hydrants at suitable distances, and see to proper arrangements for extinguishing any fires that might arise; but the most important duty to be assigned to them would be the control of building material in certain sections of the city.

"By insisting upon the construction of a row of buildings, up and down and across town, as nearly fireproof as it is possible to make them, a wall, impervious to fire and constituting a barrier impassable to any ordinary conflagration, would arrest the flames and save whole sections of the city. A street, built up entirely of fireproof buildings, would be a novelty; but in the light of recent events, it would appear to offer great protection, and it may be worth while to designate what streets shall be of this character, and then insist upon a compliance with the prescribed style of building. Having adopted some such plan as this, the commission would have to study the kind of building material best adapted to city structures, combining security and durability with reasonable economy. This opens up the whole question of the comparative value, for building purposes, of wood, iron and stone. They tried wood in Chicago, without having treated any of the material with the numerous agents that have been recommended to render it incombustible; and the sad consequences of this neglect ought to serve as a warning to all other cities. If the wood had been saturated with soluble glass, it could not have been set on fire. Silicate of soda, or soluble glass, can be obtained in sufficiently large quantities, and at such reasonable rates, as to admit of the preparation of the

shingles, clapboards, and all exposed portions of frame buildings. Any such precaution as this has the double advantage of protecting against fire, and securing against decay; and, in the long run, would be found to be the greatest economy.

"If people will insist upon constructing frame buildings in large towns, they ought to be compelled to render them essentially fireproof by the above chemical mixture. So many experiments have been tried with soluble glass, that the security it affords against fire and decay may be considered as fully determined. Wood thus prepared will char and smolder, but will not burst into flame; and hence there could be no scattering of cinders or blowing about of firebrands.

"Where frame buildings are tolerated, the fire marshal might justly insist upon a chemical preparation of the wood—an operation that could easily enough be done, if it were imperatively required. The scientific experts on the commission would be apt to report in accordance with the principles laid down above, and by degrees the dealers in lumber would learn how to furnish a building material nearly as durable as iron.

"In reference to the use of iron for houses, the facts, that it is employed to a large extent, and that we are constantly acquiring greater skill in its manipulation and management, are sufficient proof of its practicability. In Chicago, however, this material proved unavailing, for the reason that the wooden structures made a fire hotter far than a blast furnace constructed to melt pig iron. No iron could stand such a heat, and it melted down like wax. This was not the fault of the iron, but caused by the neglect to prepare the wood against such an emergency; and no one will be likely to condemn iron structures on account of their failure in Chicago.

"A third building material is stone, and this may be

divided into the native and artificial. There are a good many varieties of stone suitable for building purposes; but the cost of quarrying, transportation and working, is so great in this country as almost to shut this material out of competition. This objection does not apply to artificial stone. The lime and sand required to make artificial stone can be found nearly everywhere. They can be mixed by simple machinery, and require no labor to cut them into shape; but the plastic material can be run into any kind of a mold, where it dries in a few hours, and one layer after another can be carried up in marvelously short time.

"For rapidity of construction, for durability, for security against fire, for warmth and ventilation, for dryness and health, for economy, for architectural effects, there is nothing like artificial stone; and we look upon this material as the most suitable for cities, and as probably destined to supersede all other. It only needs the popular dissemination of information on the subject to occasion a demand for artificial stone; and as soon as such a demand is created, this material can be furnished in any quantity in all parts of the country; and we shall have it for our cellars and our ice houses, our sewers, cisterns, wells, water pipes, paths, roads, schools, churches, dwelling houses and stores, in a way that will make us wonder how we ever performed the slow and tedious labor of hewing out stones or laying up brick, when we could have formed a whole house at one casting—as Krupp pours the melted steel into molds, and produces a cannon of any size."

As regards the *Treatise on Glass Making*, which forms the second part of this work, it may be worth mentioning, that many of the western glass manufacturers have expressed their wish to be informed of the late improvements which have been going on in Europe, as far as they

have been displayed in the French Exposition of 1867, of colored, optical, plâte and other glass, all of which have silex as the base; wherefore, he resolved to begin with a full practical description of the glass house, from the first construction to the manufacture of all kinds of glass, such as the tumbler and mirror glass. The Author believes he has given as clear and succinct information as can be had, in a practical manner.

The *Soap Maker's Guide*, which forms the third part of this work, has been added for several reasons; the principal of which was, that soluble glass and fine flint have, of late years, been largely consumed in the manufacture of soap; the first as a useful vehicle for domestic use, and for washing and fulling wool, and the latter for sophisticating soaps; and the Author has taken pains to give a full description of the manipulation of raw materials used in every species of soap, and all the required information, as to be able to compete with any manufacturer; in other words, this treatise is intended as a full guide in soap making.

Since the Author has laid out this work to be altogether practical, he has omitted here the essays on the functions of carbonic acid and limestones; but the alkalies and silex in the former edition have been incorporated in the present work. Trusting that the public may accept with indulgence the following work, if in some places the phraseology or othography should sound harsh on an American ear, for the reason that the impaired state of his health frequently prevented him from bestowing the proper attention in correcting proofs; he now delivers it, confidently believing that it may prove serviceable and useful for all the intended objects.

PREFACE TO THE PRESENT WORK.

In offering the present edition to the public, the Author begs to state, that he felt induced to change his programme from the first edition, for the following reasons, viz.: The long and detailed discussions on soluble glass in the first having been received with great favor, it was advisable to add in the present all improvements which have been suggested by various authors for the last year; he has devoted in the present work two hundred pages in the description of the materials used in the manufacture and various applications of the same, to a great many branches of domestic industry.

He has omitted the philosophical essays of the first edition, on account of his resolution to publish a practical book.

The whole work is divided in three parts:

I. The soluble glass, and its various applications.
II. Glass making in all its details.
III. Soap making; a guide for the production of every species of soap, the family, toilet and silicated.

The following works have served the writer in his compilations with the greatest satisfaction, such as Muspratt's Encyclopedia, where the subject on glass is so ably treated. And in his guide for soap making he has been principally assisted by Dr. Adolph Ott's book on the art of manufacturing soap and candles.

PREFACE TO FIRST EDITION.

THE object of this Treatise on Soluble or Water Glass, is to give some information to the many inquiries which have been directed to the Author for some years past, in what manner and purpose this valuable preparation, so highly recommended by the various scientific journals, can be usefully employed. There is, as yet, no book published, treating on all its applications, with the exception of a pamphlet in French by Kuhlmann in 1859, containing mostly memoirs to the French Academy, and the application of the water glass by calico printers and cotton manufacturers. It is for this reason that the Author felt the necessity of compiling all that is scattered, about the various uses of the soluble glass, in all the journals and Patent Office reports. Not a day passes without receiving orders for samples, either in dry, liquid or jelly state, with particular requests for explicit directions; nor does a day pass without being importuned by strangers and curious people, all desirous for information how the soluble glass would answer for many purposes in domestic economy. The soap maker, who has been using it in Europe and this country for a number of years, wants to know more on the subject of producing a cheap and good soap. For slates, for a good and cheap whitewash, for a fireproof paint, for a hoop skirt or shirt collar, for a mucilage, a fire and waterproof cement, and for many hundred other uses, the inquiries are made; and thousands of samples have, for the last ten years, been distributed to the inquisitive and speculative applicants.

It is generally known that the Author was the first to introduce the soluble glass in the United States, and has devoted much time in experimenting with it; and he has succeeded, after many fruitless trials, to create a demand in many branches of industry. From the extensive list of patents issued in Europe and the United States, he has collected all information, along with that obtained from the scientific and practical journals, and experimenters will find in this Treatise the various uses and applications.. Kuhlmann's Pamphlet, the Mining and Engineering Journal, the Transactions of the American Institute, the Manufacturer and Builder, Scientific American, the Annual of Scientific Discovery, have all furnished material for this Treatise.

Many interesting topics, such as the origin of saltpetre, the nitrate of soda, and the manufacture of blanc fix, had to be related, and will, no doubt, interest the general reader.

Particular attention has been bestowed upon the formation of hydraulic cements and artificial stone, for the reason that more inquiries and experiments are performed in this branch than in any other of domestic economy. The natural stones, such as the brown stone, sandstone, limestone and brick building, will, sooner or later, after an exposure to the atmospheric elements, and rain and frost, become decomposed; cracks and fissures will then produce the deterioration, while coated with the soluble glass and mixing the mortar with the same and impregnating the bricks, much is gained for their preservation.

It is somewhat remarkable, that long before this the art of making artificial stone has not been brought to perfection. Yet, if we may judge from the great and increasing variety of processes, patented and otherwise, which now press their claims upon public notice, the time is ripe for the introduction of any process which can

demonstrate practically its capacity to fulfill the requirements of the case. Every opportunity has been afforded us to examine and test specimens of artificial stone, and we have met with many kinds which have very little merit. Some, however, are really good stones, and, as such, must, in our opinion, come largely into use.

The silicification of rail-road sleepers, wooden rails and blocks for pavement is in importance next to the preparation of artificial stone. The comparison of the wooden and iron rails has also been clearly stated here, and the future will, no doubt, bring to light many facts here stated, but not yet put to practice. The advantages of the wooden block pavement over all other kinds, such as Macadamizing, graveling, cinders, boulders, and stone blocks, are numerous, and if properly laid, will withstand long years of the hardest kind of travel; and there are but two important points in the wooden pavement to be observed, which are a firm and even foundation, and the good silicification of the foundation planks and blocks.

The reason why the Author has devoted so much space upon hydraulic limes, mortars, paints, whitewashes, and the preparation for guarding timber against dry rot and conflagration, is solely to prove and make it plausible that the application of soluble glass possesses great advantages, and may, with very little expense, give additional safeguards.

The formulæ and directions for preparing an immense number of the most useful vehicles, cements for building aud side-walks, paints, varnishes, &c., cannot but be very acceptable.

SOLUBLE GLASS,

Also called water glass, liquid quartz, or alkaline silicate, consists essentially of silex and one or two alkalies heated to fusion; it is, therefore, a silicate, either as silicate of potassa, silicate of soda, or a mixture of these two alkalies, a silicate of potassa and lime, the composition of Bohemian glass, or a silicate of soda and lime, like the English crown or spread glass; and if there is oxide of lead added to the mixture of silex and alkalies, and heated to continued fusion, we obtain thereby a flint glass, crystal glass, or strass, a paste used in mock jewelry.

According to the quantity of alkali employed in the mixture, the product is made soluble or insoluble. Bottle and window glass, for instance, which contain less alkali and some oxide of iron and alumina, (clay,) are more difficult of fusion than other kinds. The soluble glass was brought to practicable uses by Professor Fuchs, of Munich, in Bavaria, in the year 1823, by igniting strongly in a reverberatory furnace or crucible for six hours, a mixture of 10 parts of pearl ashes, 15 parts of powdered quartz, or fine sand, and 1 part charcoal; the mass was then pulverized and added in small portions to boiling water, until the whole is dissolved and evaporated to a specific gravity of 1.25, at which point the carbonic acid of the at-

mospheric air ceases to decompose it. The highest concentration of the liquid is 42° B.; when still more evaporated it is obtained in a solid form, resembling common glass, but much softer and more fusible. The liquid standing about 30° B. is, however, the most proper menstruum for application to wood, and preventing the same from being attacked or kindled by sparks of fire, such as shingle roofs, wooden bridges and farm houses. Fuchs prepared four different liquids, and employed them in his experiments:

1. The simple water glass, made from potassa.
2. The soda water glass.
3. The compound of both.
4. Another liquid which he used for fixing paints on a coating on wood, and called the jelly liquid.

In order to demonstrate the utility of the water glass in making wood fire-proof, and on the occasion of the burning of the Royal Theatre at Munich, a wooden shanty was, by order of the King, erected, and coated inside and outside with a weak liquid of silicate of potassa, and was set on fire on each corner; to the satisfaction of all spectators it resisted the element nobly, and merely charred the wooden structure without producing a life fire; and from that time the water glass was introduced in Germany. A few years later the same liquid was introduced in the manufacturing districts of England as a substitute for cow's dung by the cotton mills, and was called "Dunging Salt."

The author having studied with Doebereiner, a professor of practical chemistry in Jena, was engaged

in experiments on water glass, and who proposed an alteration in its composition, such as the compound of potash and soda, or 72 parts of carbonate of potash, 854 parts of carbonate of soda, and 152 parts of finely pulverized quartz, which proved to be a better substance, conceived the idea that water glass may be profitably employed in this country for many purposes. In company with ship captains and builders he offered to substitute it in coppering vessels, which is attended with that expensive metal, the copper sheathing, and undertook to prepare the ship's timbers in such a manner that the cells of the wood could be filled up with Silica, or, in other words, to silicify them, and produce a petrification of the organic substance, all of which at a very inconsiderable expense; in the Brooklyn Navy Yard, he was permitted by the Ordnance Department, under the direction of Commodore Perry, then the Captain of the Yard, to perform the experiments with the spiles on the various docks, which were destroyed by the worms (*Teredo navalis*) so fast that they had to be replaced every three years. Also the cannon balls exposed to the weather, becoming rusty and worthless in a few years, were varnished with his own preparation, and the addition of asphaltum, and his experiments proved highly satisfactory, as in both instances of applications many years afterwards indicated their preservation.

The water glass was neglected for many years except by the military authorities in Prussia, and we hear that the soldiers were instructed to wash their linen, and the State Prison at Spandau introduced it for washing the prisoners' under garments; and it was proved so economical, that one gallon of concentrated

liquid was sufficient for washing 1,000 pieces. The soap manufacturers began to use it in England for producing a cheap soap. Liebig devoted, in the year 1850, much attention to the subject, and at the same time Kuhlmann introduced it as a new paint under the name of stereochromic painting, for ornamenting the interior of houses. He applied the fluid silicate of potassa, obtained by dissolving flints in caustic alkali, with the aid of water of a very high temperature, to harden chalk and porous stone; for he observed that on soaking chalk with this fluid silicate, a change took place: part of the chalk, combining with the silicic acid of the silicate of potash, becoming converted into silico carbonate of lime, the carbonic acid, thus free, combined with the potash, in time, particularly when assisted by heat and dry air, the coating of silico carbonate was found to pass into a true compact deposit of silica, hard enough to scratch glass. The solution of silicate of potash could be applied either with a brush or a syringe, the surface being first cleaned and scraped. Three applications were considered sufficient. Although successful in the laboratory, this method failed when applied to buildings, because a dry atmosphere is needed during the whole period of hardening. Not long after this suggestion had been made by Kuhlmann, the English manufacturer, Ransome, of Ipswich, engaged in the manufacture of silicate of soda, following up the above experiments, attempted to fix the solution, when absorbed with the stone, to produce a double decomposition by absorbing another solution, thus leaving an insoluble deposit within the substance of the absorbent stones on which it was desired to act. He found

that, by a weak acid solution, he could set free the silica, but in that state the deposited mineral had no cohesion. Following up, however, the application of the fluid silicate by a small portion of chloride of calcium, (a waste product from the salines and acetic acid manufacturers,) it resulted that the chlorine, parting from the calcium, attacked the soda of the silicate, forming common salt, which is easily dissolved away, while the silicic acid, set free, combining with the lime, formed with it silicate of lime. This mineral is nearly insoluble, very hard, and adheres with great tenacity to foreign substances, as is illustrated in common mortar. Silicate of lime thus formed resists carbonic acid and dilute sulphuric acid, and is little affected by any of the common alkalies or ammonia.

The effect of this treatment on stones that have not already been inserted into buildings has been very favorable; and they appear to have stood without decay under exposures sufficient to have produced much injury on the same stone unprotected and applied on a large scale to buildings that have already shown symptoms of decay, the result is less satisfactory; but years must elapse before a very decided opinion can be given on the process. After some time we will be able to see the result in the Houses of Parliament and Westminster Abbey, where the magnesian limestone has been treated by this process.

A combination of Kuhlmann's process with a temporary wash of some bituminous substance has been tried on a large scale in the Speaker's Court of the Houses of Parliament, by Szereling, which will likewise be decided after some time upon its superiority.

The manufacture of the water glass or soluble sili-

cate, or soluble glass, has only been known since our present time, although the various kinds of glass, imitation of gems, belongs to antiquity; for Pliny states "that glass was first discovered by accident in Syria, at the mouth of the River Belus, by certain merchants driven thither by the fortune of the sea, and obliged to continue there and dress their victuals by making a fire on the ground, where there being a great store of the herb *kali*, that plant burning to ashes, its salts, mixed and incorporated with sand or stones fit to vitrify or make glass." The word kali was explained by Boerhave as one of the materials of glass, *salt* and *sand;* "the salt here used is procured from a sort of ashes, brought from the Levant, called polverine or rochetta, which ashes are those of a sort of water plant called kali, of the species of that found in some parts of England, called frog-grass, or crab-grass, cut down in summer, dried in the sun, and burnt in heaps, either on the ground or on iron grates, the ashes falling into a pit, grow into a hard mass or stone, fit for use." This material evidently means the kelp, which was burnt and converted into Barilla. It is also certain that Kunkel, in 1679, states that the art of glass was already brought to its highest perfection, and expressed that Neri, in his treatise "De Arte Vitraria," has communicated complete knowledge of artificial gems. Much is said of flexible glass not rotting, of a fusible or soluble glass, of which Van Helmont, the chemist of the first part of the seventeenth century, knew nothing. The improvements in the manufacture of the soluble glass, particularly that of soda, were of great importance. He had, in the first place, discarded the sand, which he did not find compact

enough for producing a good paint, and substituted the flints, found in the chalk: this species of silex he exposes under a pressure of 7–8 atmospheres, in an iron cauldron, to a hot soda lye standing 38°, which process was patented by the brothers Siemens, in the year 1845, with this difference, that they produce a liquid at a very high temperature corresponding in vapors of 4–5 atmospheres, by which process they obtain 3–4 times the quantity of silica to a thin liquid.

Liebig proposes the employment of the infusorial earth, which dissolves readily the caustic soda lye, whereby he obtains 240 parts of silica jelly from 120 parts infusorial earth, and 75 parts soda ash. It is well known that the infusorial earth is pretty pure silica of 87 per cent. and 8 per cent. water. The beds of Bilin, in Bohemia, and belonging to the fresh water Tertiary, have a thickness of 14 feet, also in Planitz, in Saxony. Ehrenberg estimates that about 18,000 cubic feet of the siliceous organisms are annually formed in the harbor of Wismar, in the Baltic Sea; the deposit of infusorial earth in Richmond, Va., contains over 100 species, and forms a thick stratum.

SILEX, OR SILICA.

This substance is an oxide of silicium, and being the main body of our preparation, deserves a full and detailed description.

Silicium is the metallic basis of silica, or silex, and is equally abundant with oxygen as a constituent of the solid surface of the globe, also constituting a large portion of aerolites, from the region of space. This metallic base was discovered by Berzelius, in 1823, and is obtained artificially in the following manner: Well dried silico fluoride of potassium, 10 parts, are mixed with 8 or 9 parts potassium in an iron or glass tube, and the potassium fused and stirred with the salt by an iron wire. It is then heated by a spirit lamp, when it suddenly becomes ignited from the reduction of silica by the potassium forming a brown mixture of fluoride and siliciuret of potassium. It is thrown in cold water, when hydrogen is evolved, the potassium of the silica not being oxydized by water and the silicium separating. When the effervescence has ceased, the solution is poured off, fresh cold water added and poured off, until it ceases to be alkaline, when boiling water is used to wash the silicium as long as it extracts any thing.

Silicium is inflammable in the air, by heat, about one-third burning to silica, which, removed by fluohydric acid, leaves a dark, chocolate, brown powder, heavier than oil of vitriol, is combustible either in the

air or oxygen, or even when gently ignited with saltpetre.

Silica, or oxide of silicium, is synonymous with silicic acid, silex and pure sand, or quartz, in its various forms and appearances, and constitutes a very large proportion of the solid crust of the globe ; is the principal constituent of all simple minerals, and forms a greater variety of salts than any other acid. It is easily prepared pure from powdered quartz, sand, felspar, or other silicious minerals, by fusing them with four times their weight of a mixture of carbonate of potassa and soda, or by either carbonate alone, dissolving them in dilute muriatic acid, filtering and evaporating the solution to dryness by a gentle heat, digesting in muriatic acid, filtering and washing with hot water.

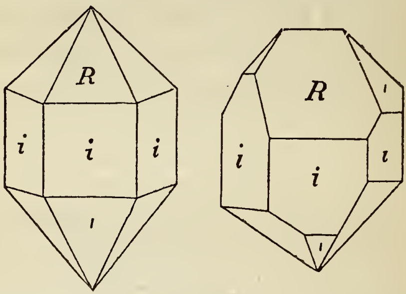
This silica has two modifications, the one soluble in water and acids, the other insoluble. The soluble is that obtained in the above process for preparing silica, and is always formed by fusing silicates with alkalies, but may also be formed by boiling fine Silex with strong alkaline solutions.

It is soluble in water and acids, and when the solutions are concentrated it usually separates as a jelly, [gelatinous silica,] and when evaporated to dryness, passes into the insoluble modification.

Silica is a white, gritty powder, insoluble in water and acids, infusible in the highest heat of our furnaces, but fusible in a stream of oxygen driven through an alcohol flame. It fuses in this case to a clear glass, which may be drawn out into flexible threads. When the fused bead is dropped in water, it becomes so hard as to indent a steel pestle and mortar. It is the fee-

blest acid at common temperatures, but by a high heat can expel all volatile acids.

Quartz is found in nature crystalized in a great variety of forms, the rhombohedral prevailing, and for the most part hemihedral to the rhombohedron, or tetrahedral to the hexagonal prism. The annexed two figures give some idea of its occurrence:



The cleavage is very indistinct, sometimes effected by plunging a heated crystal in cold water. The crystals are either very short or very much elongated, sometimes fine acicular usually implanted by one extremity of the prism, occasionally twisted or bent. The prismatic faces commonly striated horizontally, and thus distinguishable, in distorted crystals from the pyramid. Crystals often grouped by juxtaposition, not proper twins, frequently in radiated masses with a surface of pyramids, or in druses having a surface of pyramids or short crystals. Herkimer and Ulster counties, of the State of New-York, produce quartz crystals of the most complicated forms, which occur from the size of a pin's head to that of a foot. Quartz is also found massive, from the coarse or fine granular to flint-like or crypto-crystaline; sometimes mammillary stalactitic, and in concretionary forms.

Quartz has a hardness, 7, and a specific gravity of 2.65 ; a vitreous lustre sometimes inclining to resinous ; splendent and nearly dull ; is colorless when pure, but often having various shades of yellow, red, brown, green, blue and black. The streak is white of pure varieties ; of impure often the same as the colors, but much paler. Quartz is transparent and opaque ; its fracture is perfect conchoidal and subchonchoidal, is tough, brittle and friable. The polarization of quartz is circular, there being a colored centre instead of a central cross, and the rings of color around enlarging as the analyzer is turned to the right in right-handed crystals, or left, in left-handed, and colored spirals are seen, which rotate to the right or left when the incident light and emerged light are polarized, one circularly, and the other plane.

Pure silica, which has the symbol of $\dddot{\mathrm{Si}}$, consists of 53.33 parts oxygen, and 46.67 silicon=100. It is unaltered if brought alone before the blow-pipe, but with soda it dissolves with effervescence ; it is unacted upon by any salt of phosphorus ; it is only soluble in fluohydric acid. There are two varieties of quartz in existence :

I. The crystalized, or phenocrystaline, which is vitreous in lustre.

II. The fluid-like, massive, or crypto-crystaline.

The first division includes all ordinary vitreous quartz, whether having crystaline faces or not ; while the second variety has been acted upon somewhat more by attrition and chemical agents, as fluoric acid, than those of the first.

I. The following species of quartz belong to the phenocrystaline, or vitreous varieties:

1. The ordinary crystalized quartz, rock crystal, which is the colorless quartz, or nearly so, whether in distinct crystals or not.

a. The regular crystals, or limpid quartz.

b. The right-handed crystals.

c. Left-handed crystals.

d. Cavernous crystals, having deep cavities parallel to the faces, occasioned by the interference of impurities during their formation.

e. Cap quartz, made up of separable layers or caps, owing to the deposit of a little clayey material at intervals in the progress of the crystal.

f. Drusy quartz, a crust of small or minute quartz crystals.

g. Radiated quartz, often separable into radiated parts, having pyramidal terminations.

h. Fibrous, rarely delicately so, from Cape of Good Hope.

2. Asteriated quartz, star quartz, containing within the crystal whitish or colored radiations along the diametral planes. Part, if not all, asteriated quartz is asteriated in polarization, as already remarked.

3. Amethystine quartz, amethyst, clear, purple or blueish-violet; the color is supposed to be due to manganese; the shade of violet is usually deepest parallel to the planes R.

4. Rose, rose red or pink quartz. It becomes paler on exposure, common, massive; and then usually

much cracked, lustre sometimes a little greasy. The action is, according to Fuchs, due to titanic acid; the general impression is, however, that its color is owing to manganese.

5. Yellow, false topaz, yellow and pellucid, or nearly so, resembling somewhat yellow topaz; but very different in crystalization, and in absence of cleavage.

6. Smoky quartz; the Cairngorm stone. It is smoky yellow to smoky brown, and often transparent, but varying to brownish black, and then nearly opaque, in thick crystals. The color is probably due to titanic acids, as crystals containing rutile are usually smoky. It is called Cairngorm, from the locality in Scotland.

7. Milky, milk white, and nearly opaque; lustre often greasy, called then greasy quartz.

8. Siderite, or sapphire quartz, of indigo, or Berlin blue colors. A variety of quartz occurring in an impure limestone at Golling, in Salzburg.

9. Sagenitic, containing within acicular crystals of other minerals: these acicular crystals may be rutile, or black Tourmaline, or Gœthite, stilbite, asbestos, actinolite, hornblende, or epidote.

10. Cat's eye, exhibiting opalescence, but without prismatic colors, especially when cut in cabochon, an effect due to fibres of asbestos.

11. Aventurine quartz, spangled with scales of mica or other mineral.

12. Impure quartz, from the presence of distinct minerals distributed densely through the mass, such as ferruginous, either red or yellow oxide of iron,

chloritic from chlorite, actinolitic, micaceous, arenaceous owing to sand.

Quartz crystals also occur penetrated by various minerals, as topaz, corundum, chrysoberyl, garnet, different species of hornblende and Pyroxene groups, kyanite, zeolites, calcite and of rutile, stilbite, hematite, Gœthite, magnetite, fluorite, gold, silver, anthracite, &c. As quartz has been crystalized through the aid of hot waters or of steam in all ages down to the present, and is the most common ingredient of rocks, there is good reason why it should thus be found the enveloper of other crystals.

13. Quartz containing liquids in cavities. These liquids are seen to move with the change of position of the crystal, provided an air bubble be present in the cavity; they may be detected also by the refraction of light; the liquid is either pure water, or a mineral solution, or petroleum-like liquid.

II. The crypto-crystaline varieties of quartz are the following:

1. Chalcedony; it has the lustre nearly of wax, and is either transparent or translucent; the color is white grayish, pale brown to dark brown, black, tendon color common, sometimes delicate blue; also of other shades, and then having other names; it is often mammillary, botryoidal, stalactitic, and occurring lining or filling cavities in rocks.

2. Carnelian; a clear red chalcedony, pale to deep in shade, also brownish red to brown; the latter called sardonyx, reddish brown by transmitted light.

3. Chrysoprase; an apple green chalcedony; the color is due to the presence of oxide of nickel.

4. Prase; translucent and dull leek green; taking its name from the Greek πρωσόν, a leek.

5. Plasma; a rather bright green to leek green, and sometimes nearly emerald green color, and sub-translucent or feebly translucent, sometimes dotted with white.

Heliotrope, or bloodstone, is the same stone essentially, with small spots of red jasper, looking like drops of blood.

The jasper of the ancients was a semi-transparent or translucent stone, and included, in Pliny's time, all bright colored chalcedony, excepting the carnelian; the same author gives special prominence to sky blue and green, and mentions also a shade of purple, a rose color, the color of the morning sky in autumn; sea green, serpentine color, (yellow, like serpentine,) smoke color, but in general there is a tinge of blue, whatever the shade.

6. Agate; a variegated chalcedony; the colors are either banded or in clouds, or due to visible impurities.

(Banded agate,) where the bands form delicate parallel lines of white, tendonlike, waxlike, pale and dark brown and black colors, and sometimes bluish and other shades, they follow waving or zigzag courses, and are occasionally concentric circular, as in the eye agate. The fine translucent agates graduate into coarse and opaque kinds. The bands are the edges of layers of deposition, the agate having been formed by a deposit of silica, from solutions intermittently supplied in irregular cavities in rocks, and deriving their concentric waving courses from the irregularities of the walls of the cavity. As the cavity can-

not contain enough of the solution to fill it with silica, an open hole has been supposed to be retained on one side to permit the continued supply, but it is more probable that it passes through the outer layers by osmosis, the denser solution outside thus supplying silica as fast as it is deposited within. The colors are due to traces of organic matter, or oxides of iron, manganese, or titanium, and to differences in rate of deposition. The layers differ in porosity, and therefore in the rate at which they are etched by fluoric acid, the etching process brings out the different layers, and makes engravings that will print exact pictures of the agate. Owing also to the unequal porosity, agates may be varied in color by artificial means.

Irregularly clouded agate, the colors various, as in banded agate.

A whitish, clouded variety, which Pliny has described and given fully the characters.

Colored agate, due to visible impurities; a moss agate, or mocha stone, filled with brown moss-like or dentritic forms, distributed through the mass of dentritic agate, containing brown or black dentritic markings. These two have been fully described by Pliny as dentrachates.

There are also eight agatized woods, wood petrified with clouded agate.

7. Onyx, like agate, in consisting of layers of different colors, but the layers are in even planes, and the banding therefore straight, and hence its use for cameos, the head being cut in color, and another serving as the background.

The colors of the best are perfectly well defined,

and white and black, or white, brown and black alternate.

8. Sardonyx, like onyx in structure, but includes layers of carnelian, along with others of white, or whitish and brown, and sometimes black colors.

9. Agate jasper. An agate consisting of jasper, with veinings and cloudings of chalcedony.

10. Siliceous sinter. Irregular cellular quartz, formed by deposition from waters containing silica, or soluble silicates in solution.

11. Flint. Somewhat allied to chalcedony, but more opaque and of all colors, usually gray, smoky brown and brownish black. The exterior is often whitish, from mixture with lime or chalk, in which it is imbedded. Lustre barely glistening, subvitreous; breaks with a deeply conchoidal fracture and a sharp cutting edge. The flint of the chalk formation consists largely of the remains of infusoria, sponges, and other marine productions. This mineral contains, according to Fuchs, partly soluble silica.

12. Hornstone. It resembles flint, is more brittle, and fracture more splintry. Chert is a term often applied to hornstone, and to any impure flinty rock, including the jaspers.

13. Basanite, lydian stone, or touchstone. A velvet black siliceous stone or flinty jasper, used on account of its hardness and black color for trying the purity of the precious metals. The color left on the stone after rubbing the metal across it indicates to the experienced eye the amount of alloy. It is not splintry like the hornstone: it passes into a compact, fissile, siliceous or flinty rock, of grayish or other col-

ors, called siliceous slate, and resembles ordinary jasper, of various shades.

14. Jasper. An impure opaque colored quartz.]

- *a.* The reducing to hematite, or sesquioxide of iron.
- *b.* The yellow or brown, colored by the hydrous sesquioxide of iron, and becoming red when so heated as to drive off the water.
- *c.* The dark green and brownish green.
- *d.* The grayish blue.
- *e.* Blackish or brown black.
- *f.* Striped or ribbon jasper, having the colors in broad stripes.
- *g.* Egyptian jasper in nodules, which are zoned in brown and yellow colors.

Porcelain jasper is nothing but a baked clay, and differs from true jasper in being fusible on the edges before the blowpipe. Red porphyry, or its base, resembles jasper, but is also fusible on the edges, being usually an impure felspar.

Quartz is also found in the following forms:

1. Granular quartz, or quartz rock, which consists of quartz grains very firmly compacted, the grains often hardly distinct.

2. Quartzose sandstone.

3. Quartz-conglomerate. A rock made of pebbles of quartz with sand. The pebbles are sometimes jasper or chalcedony, and make a beautiful stone when polished.

4. Itacolumite, or flexible sandstone. A friable sand rock, consisting mainly of quartz sand, but con-

taining a little talc, and possessing a degree of flexibility when in thin laminae.

5. Buhrstone. A cellular flinty rock, having the nature in part of coarse chalcedony.

6. Pseudomorphous quartz. Quartz appears also under the forms of many of the mineral species, which it has taken through either the alteration or replacement of crystals of those species. The most common quartz pseudomorphs are those of calcite, baryta, fluorite and siderite. Tabular quartz, Haytorite, Beckite, Babel quartz, silicified shells and silicified wood are found pseudomorphized by other minerals, either of carbonate lime, Datholite, fluorspar, shells and wood. The texture of the wood, for instance, is well retained, it having been formed by the deposit of silica, from its solution in the cells of the wood, and finally taking the place of the walls of the cells as the wood itself disappeared.

Dissolved quartz, or liquid silica, occurs often in heated natural waters, as those of the Geysers of Iceland, New-Zealand and California, mostly as a soluble alkaline silicate.

Quartz is one of the essential constituents of granite, sienite, gneiss, mica, schist and many related rocks. As the principal constituent of quartz rock and many sandstones; as an essential ingredient in some trachyte porphyry, &c.; as the veinstone in various rocks, and for a large part of mineral veins; as a foreign mineral in the cavities of trap, basalt and related rocks, some limestones, &c., making geodes of crystals or of chalcedony, agate, carnelian, &c., as imbedded nodules or masses in various limestones containing the flint of the chalk formation, the hornstone of other limestones;

these nodules becoming sometimes layers or masses of jasper occasionally in limestone. It is the principal material of the pebbles of gravel beds and of the sands of the seashore and river sandbeds.

Independent of the quartz proper, as has been just described, nature produces a vast many minerals composed either solely of silica, with slight variations in their degree of hardness or specific gravity, such as the following:

The opal, which is subdivided, in

1. The *precious opal*, exhibiting a play of delicate colors.

2. The *fire opal*, of hyacinth red to honey-yellow colors.

3. The *girasol*, of bluish white color, with reddish reflections in a bright light.

4. The *common opal*, in part translucent, and milk-white to greenish, yellowish, bluish. Resin opal, wax or honey color, with resinous lustre. Olive green opal; brick-red opal; hydrophane, a translucent opal, whitish or light colored, adheres to the tongue, and becomes more translucent or transparent in water, wherefore its name. An orange, yellow opal, called Forcherte; it is colored by orpiment.

5. *Cachelong.* Opaque and bluish white, porcelain white; often adheres to the tongue.

6. *Opal agate.* Agatelike in structure, but consisting of opal of different shades of color.

7. *Menilite.* In concretionary forms, tuberose, reniform; opaque, dull gray and grayish brown.

8. *Jaspopal.* An opal, containing some yellow oxide of iron, and having the color of yellow jasper.

9. *Wood opal.* Wood petrified by opal.

10. *Hyalite.* Clear as glass and colorless, constituting globular concretions and crusts.

11. *Fiorite*, or siliceous sinter; also called pearl sinter, from Santa Fiora, in Italy, and other volcanic rocks, formed from the decomposition of the siliceous minerals of volcanic rocks, or from the siliceous waters of hot springs.

12. *Float stone;* also called swimming quartz; is light, concretionary or tuberose masses, white or grayish, sometimes cavernous.

13. *Tripolite.* Infusorial earth; formed from the siliceous shells of diatomous and other microscopic species, occurring in deposits often miles in area, either uncompacted or moderately hard.

a. Infusorial earth, or earthly tripolite, is a very fine grained earth, looking often like an earthy chalk or clay; but harsh to the feel, and scratching glass, when rubbed on it.

b. Randanite; a kaolin-like variety from France.

c. Tripoli slate. A slaty or thin laminated variety; fragile, often mixed with clay, magnesia and oxide of iron.

d. Alumocalcite. A milk-white material, very light, having a hardness of only 1 to $1\frac{1}{4}$, and a sp. gr. of 2.174, and probably a variety of tripolite.

This mineral is, probably, the most economical and useful material for the manufacture of the soluble glass.

The opal family is likewise a quartz, but a little softer and contains some water, is soluble in a heated solution of potash, while quartz is not.

In England and France the flints from the chalk are mostly employed in the manufacture of soluble glass; but in the United States clear sand, from the river-bed of New-Jersey and Mississippi rivers, are solely used in its manufacture. Sand generally consists of particles of quartz, but there is also a granitic sand, containing particles of felspar as well as quartz, where it has not been long enough exposed to meteoric agents to decompose the felspar. Sand usually consists of grains more or less rounded, but sometimes angular, and then preferable for mortar. There are several varieties of the sandstone, such as *micaceous*, *argillaceous*, *marly* and *flexible*. *Common sand* is mainly comminuted quartz. *Gravel* is a mixture of sand with pebbles. *Volcanic sand* is sand of volcanic origin; either the cinders or ashes, or comminuted lava. *Alluvial sand* is the earth deposited by running streams, especially during times of flood; it constitutes the flats on either side of the stream, and is usually in thin layers, varying in fineness or coarseness, being the result of successive depositions. In order to use the sand for the manufacture of soluble glass, which shall equal that manufactured from flint, or infusorial or siliceous earth, it is best to digest the sand with chlorohydric acid, which is capable of dissolving all the foreign substances, and then by frequent washings and dryings in the sun, produces a pretty pure silica. Iron, clay, lime, which are, more or less, found in the mud, may easily be detected by the various chemical tests, such as by ammonia, the iron; by oxalate of ammonia, the lime; and clay, by carbonate of soda.

If the pure crystalized quartz, flint or hornstone

should be used for the manufacture, the same must be reduced into coarse or granular condition, which is effected by calcining the mineral, and when red hot, cold water is thrown over it, whereby it becomes disintegrated and falls to pieces, and it is then ground in mills used by the glass manufacturers.

Before closing the chapter of silica, it must be stated that nature has given us a vast variety of silicates; that the alkaline silicates of soda, potash and lime, which are called the soluble silicates, are spread over the globe in such quantities, like oxygen compounds, with the addition of many other bases in nature, that there are very few mineral substances known in which silica, representing the acid, is not combined with the various elements, and forming silicates which are again divided in anhydrous and hydrous silicates, all of them having ternary oxygen compounds. The anhydrous silicates are again subdivided, as 1. *Bisilicates;* 2. *Unisilicates;* and 3. *Sub-silicates;* while the hydrous silicates are again divided in various sections. The whole crust of the globe consists in silicates. The felspar mica is a pure silicate. We have a soda felspar, and a potash felspar, and a lime felspar, while the mica is a compound of silica combined with some other bases, such as alumina, magnesia, &c. The zeolites form a large class of silicates, which resemble the felspar, but contain water, and are less hard and more fusible, such as the analcime, chabasite, stilbite, heulandite, &c.

THE ALKALIES, &c.

In the manufacture of soluble glass, the alkalies are, in importance, next to the quartz or silica, such

as the soda and potash, both of which are employed as the carbonates, which ought to be pure.

The carbonate of potash, which is the pearlash, must be free from foreign saline substances. The glass manufacturers prepare that material by washing it freely with water and evaporating the solution to the formation of a precipitate of salt, and then the water is run off.

The *Soda* employed in the manufacture is the soda ash of commerce, and is never pure enough, containing water and other salts, which ought to be removed from it by dissolving, crystalizing, and then calcination of the crystals.

Sulphate of soda, or Glauber salt, has been used by some manufacturers in place of soda ash, which ought not to be employed, as the same is partly converted into sulphide or sulphuret and oxsulphite of sodium, which is detrimental.

Fluorspar, a fluoride of calcium, may be added to the mixture of sand and alkali, as it produces a more fusible silicate, which will harden soon after application by the affinity for this alkali. In the production of hard cements, the fluohydric acid is of great service, for it assists in the hardening of the mortar, and forming a good, permanent cement.

White arsenic in powder, [arsenious acid,] and *nitrate of soda*, are used in this composition; they produce a white soluble glass; while, without any admixture, the product is green. From three to eight per cent. of either is used.

THE MANUFACTURE OF SOLUBLE GLASS.

I. The POTASH SOLUBLE GLASS.

It is obtained by mixing 15 parts powdered quartz or pure sand with 10 parts purified pearl ashes, and 1 part charcoal, in a Hessian crucible, and exposing the mixture so long to a heat until the mass after six hours has become vitrified. Charcoal is employed for assisting, by its decomposition, the production of carbonic acid, as also some sulphuric acid which may have been produced. It is at present, however, omitted, and if manufactured on a large scale the vitrification is done in a reverberatory furnace capable of holding from 1,200 to 1,500 pounds. The ashes and sand must be well mixed together for some time, and the furnace must be very hot before throwing the mixture in it, and must be constantly kept up until the entire mass is in a liquid condition.. The tough mass is then raked out and thrown upon a stone hearth and left to cool. The glass mass so obtained appears to be hard and blistery, of blackish gray color, and if the ashes were not quite pure it will also be adulterated with foreign salts. By pulverizing and exposing it to the air it will absorb alkali, and by degrees the foreign salts will, after frequent agitation and stirring, be completely separated, particularly after pouring over the mass some cold water, which dissolves them, but not the soluble glass. The purified mass is now put into an iron cauldron, containing five times the quan-

tity of hot water, in small portions, and with constant agitation, and replacing occasionally hot water for that which evaporated during the boiling, and after five or six hours the entire mass is dissolved; the liquid is removed and left to settle over night, in order to be able to separate any undecomposed silex. The next day it is evaporated still more, until it has assumed the consistency of a syrup, and standing 28° B., and is composed of 28 per cent. potash, 62 per cent. silica and 12 per cent. water. It has an alkaline taste, and is soluble in all proportions of water, and is precipitated by alcohol, and if any salts do effervesce they may be wiped off. The color is not quite white, but assumes a greenish or yellowish white color.

II. The MANUFACTURE OF SODA SOLUBLE GLASS: To 45 parts silica or white river sand are added 23 parts carbonate of soda fully calcined, and 3 parts charcoal, and is then treated in the same manner as the other glass. The proportions of the mixture are altered by the different manufacturers; some propose to 100 parts silex, 60 parts anhydrous glauber salt and 15 to 20 parts charcoal. By the addition of some copper scales to the mixture, the sulphur will be separated. Another method is proposed by dissolving the fine silex in caustic soda lye. Kuhlmann employs the powdered flint, which is dissolved in an iron cauldron under a pressure of 7 to 8 atmospheres. According to Liebig the infusorial earth is recommended in place of sand, on account of being readily soluble in caustic lye, and he proposes to use 120 parts infusorial earth to 75 parts caustic soda, from which 240 parts silica jelly may be obtained. His mode is to calcine the earth so as to become of white colors, and passing it through sieves.

The lye he prepares from 75 ounces calcined soda, dissolved in five times the quantity of boiling water, and then treated by 56 ounces of dry slacked lime; this lye is concentrated by boiling down to 48° B.; in this boiling lye 120 ounces of the prepared infusorial earth are added by degrees, and very readily dissolved, leaving scarcely any sediment. It has then to undergo several operations for making it suitable for use, such as treating again with lime water, boiling it, and separating any precipitate formed thereby, which, by continued boiling, forms into balls, and which can then be separated from the liquid. This clear liquid is then evaporated to consistency of syrup, forms a jelly slightly colored, feels dry and not sticky, and is easily soluble in boiling water.

The difference between potash and soda soluble glass is not material; the first may be preferred in white washing with plaster of Paris, while the soda glass is more fluidly divisible.

It may be observed, that before applying either soluble glass, it ought to be exposed to the air for ten to twelve days, in order to allow an efflorescence of any excess of alkali, which might act injuriously. There are, however, many methods proposed to obviate this difficulty, and which will be mentioned hereafter.

III. The DOUBLE SOLUBLE GLASS.

This is a compound of potash and soda, is prepared from 100 parts quartz, 28 parts purified pearl ashes, 22 parts anhydrous bicarbonate of soda, 6 parts of charcoal, which are spread in such manner as already described. If the mass is fully evaporated to dryness, forms a vitreous solid glass which cannot be scratched

by steel, has a conchoidal fracture, of sea-green color, translucent and even transparent, has a specific gravity of 1.43.

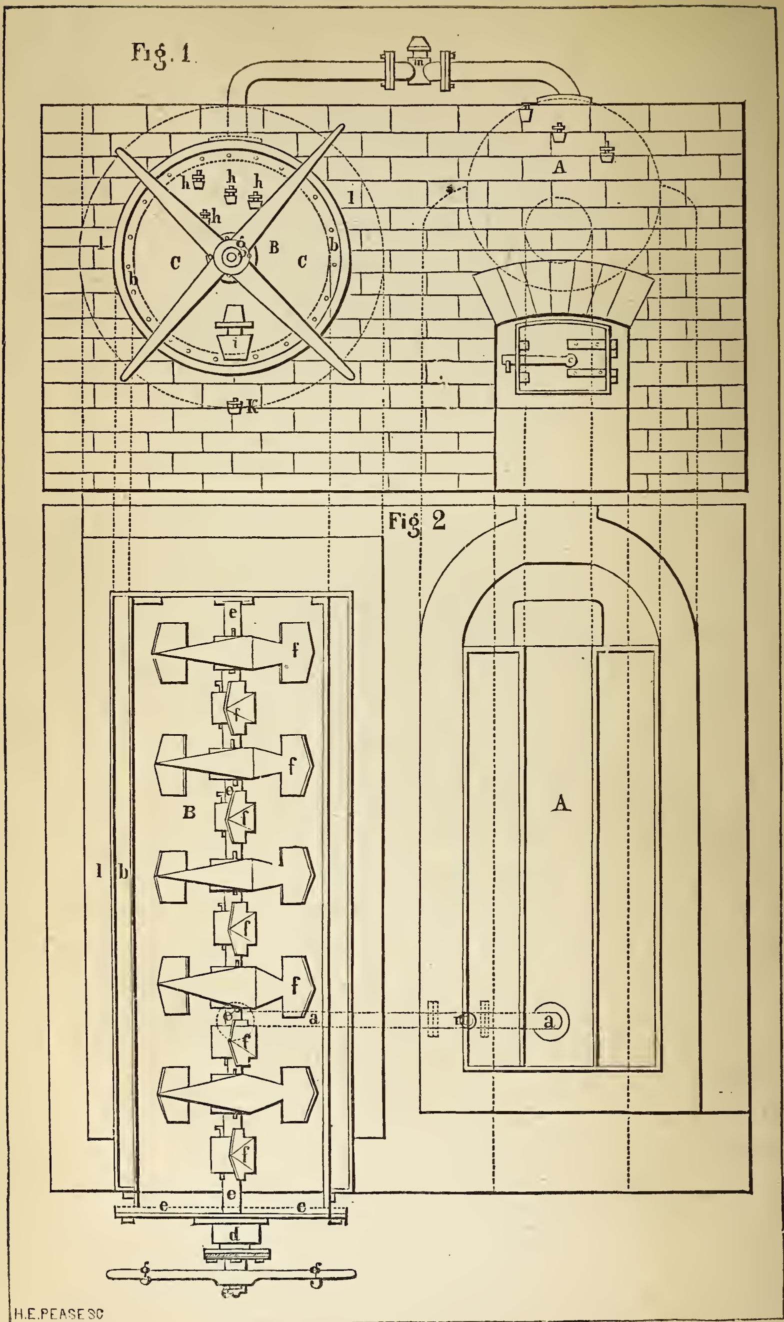
IV. The SOLUBLE GLASS, after Kaulbach, for the use of sterro-chromic painting.

It is obtained by fusing 3 parts of pure carbonate of soda and 2 parts powdered quartz, from which a concentrated solution is prepared, and 1 part of which is then added to 4 parts of a concentrated and fully saturated solution of potash glass solution, by which it assumes a more condensed amount of silica with the alkalies; and which solution has been found to work well for paint. Siemens' patent for the manufacture of soluble glass consists in the production of a *liquid quartz*, by digesting the sand or quartz in a steam boiler tightly closed, and at a temperature corresponding to 4–5 atmospheres, with the common caustic alkalies, which are hereby capacitated to dissolve from three to four times the weight of silica to a thin liquid. The apparatus, which was patented in 1845, is well known in this country; as some persons, many years later, obtained a patent for the same apparatus in the United States, which on inspection does not differ from that of Siemens Brothers.

Description of Siemens' Apparatus for dissolving silica in soda lye, under a pressure of five atmospheres, or sixty pounds to the square inch:

APPARATUS FOR DISSOLVING QUARTZ,

UNDER PRESSURE OF FIVE ATMOSPHERES.



The whole apparatus consists of the boiler A and the dissolving kettle B.

Fig. 1 represents the front side, and 2 the horizontal. A and B are connected by the pipe *a*. The kettle B is constructed of two strong walls, with a space *b* of the width of 1–2 inches.

The steam passes through the pipe *a* into the space *b*. In order to reach the inner kettle, which is perfectly tight, the wall *c* has to be unscrewed. Under the middle of this wall the box *d* is now attached, which encloses the iron pipe *e*, passing through the length of the kettle. Then the shovels, or agitators, *f f*, are now applied with the wheel *g* at the end for effecting the revolutionary movement. The steam-cocks *h*, as seen at the front wall *c*, for indicating the stage of the water in the interior kettle; the cock *i* serves for pumping and discharging the solution, and the cock *k* for letting off the water, which was condensed in the steam chamber C.

The outer kettle is surrounded with ashes, or any other non-conducting substance.

The boiler is supplied with ventils and manometers, and the kettle B. is tested to stand a pressure of 80–100 pounds per square inch.

The kettle is now filled with the necessary quantity of silex, after the front wall has been screwed on by means of the cock *i*, and is filled up with the caustic lye, which is composed of 100 lbs. carbonate of soda to 20 gallons water, and 1 lb. of silex for each quart of water; when filled, and the steam having assumed the tension of 60 lbs. to the square inch, as indicated by the safety ventil, the cock *m* is opened, when the steam passes to the other kettle, and condenses on the

cold wall of the inner kettle; here the temperature is raised, and assumes soon a pressure of sixty pounds, which point is indicated by the escape of steam from the safety valve. Fire is now kept up for six to eight hours under a constant escape of vapor.

During all this time the shovels or agitators are kept in motion by the workmen, and then the silex contained in the kettle will have dissolved from 80–90 per cent., and is drawn off, and may be re-filled for a new operation.

The apparatus may undergo some modification as the agitators get a different form, etc., etc.

The silica to be employed is, as already stated to be, the common sand, which is at first calcined and thrown in water; when dry, it is ground as fine as flour.

The liquid silica when discharged from the kettle may be evaporated to dryness, when it assumes a compact mass, a vitreous and conchoidal fracture and a hardness, so as to give sparks on steel, without the brittleness of flint.

The solution as it is obtained from the kettle may be converted into a white fine stone, by adding fine sand, until it assumes a plastic mass, say 3–4 parts, with the addition of a little chalk or lime and white clay; by exposing this mass when formed into pressed stones or objects to the atmosphere for some time, the stone is now in the best condition.

Instead of fine sand, fine powdered dry silicate may be substituted, and a better stone thereby obtained.

When the mass is dried, it must undergo the pressure of a hydraulic press.

The addition of chloride of calcium and chloride of

iron, either in liquid state or in dry powders, is highly recommended for promoting the hardening process.

Siemens' remarks of the application of the silex liquid, that the sand to be employed must be first calcined and then thrown into cold water, and afterwards ground into fine powder, which, when mixed with his liquid, becomes compact, insoluble and white, possessing a vitreous and conchoidal fracture, and a hardness so as to give sparks by steel.

The same gentleman also recommends for the production of a white stone, to work up the fine silex with so much liquid soluble glass so as to form a plastic mass, say from 3–4 parts of the sand may be required, similar to potter's clay, and adding, at the same time, a small quantity of chalk and fine clay, whereby the mass becomes more uniform and compact. Prepared in this manner, objects moulded or pressed from the mass must be exposed to the air for some time.

For monuments, millstones and other building material, he uses 1 part liquid silica to 2 parts fine sand and 12 parts coarse sand, which mass, formed into the desired sizes or objects, after being dried long enough in the air, are left in a heated room of 75° for several days, and even to the boiling point of water; they become so hard, after a lapse of four to six days, that they never crack or fall to pieces. It is also recommended to expose the mass to the pressure of a hydraulic press before exposing to the air. For obtaining a cement—roofing and wall body—it is advisable to add the chloride of calcium to the mass, and thereby the excess of alkali is absorbed.

The mass so formed may be steeped in a solution of chloride of calcium, or chloride of iron, before exposing to the atmosphere. In all these cases the silica ought to be employed very concentrated, even in jelly form.

The uses of the soluble glass are here condensed in a short sketch, intended as a circular to those desirous of obtaining some information:

"THE USES OF *SOLUBLE GLASS (LIQUID SILEX,) SILICATE OF SODA, SILICATE OF POTASH, SILICATE OF SODA AND POTASH (COMBINED.)

"Liquid silica is now employed in the arts for many useful purposes, and particularly for preserving stone buildings from decomposition; for preparing an artificial stone, and thereby reducing the price of building, and making a composition more ornamental. Its introduction for architecture is but of recent date, and the true and proper method of application not yet on an infallible base; but the subject is of so vast importance, that experiments are continually going on for making a perfect stone from its original ingredients.

"The cause of gradual decomposition of building stone is attributed to the expansion and contraction of water absorbed, as well as to the chemical action of carbonic acid of the atmosphere, which abstracts portions of the gases from the silicates, and liberat-

---

* In the year 1832 Dr. F. prepared a quantity of soluble glass for the U. S. Government to preserve the cannon, guns and bomb-shells from rust or oxydation at the Navy Yard in Brooklyn, to the fullest satisfaction of the late Commodore Perry.

ing thereby silica. Many palaces in Europe, churches and other public buildings, have been refinished by the silicate, such as the Louvre and Notre Dame Cathedral in Paris, the Houses of Parliament in London, and in other cities. Still, its general application has met with many failures. It was found that rain counteracted the effect before the alkali has had time to take up a sufficient quantity of carbonic acid from the atmosphere and to liberate the insoluble silicate; the coating will produce cracks, and a gradual disintegration of the surface or compound is caused thereby. Numerous remedies were suggested to counteract this evil—the chloride of calcium, oxychloride of magnesium, the bittern of the salines, and hydrofluoric acid. At present, a concrete stone of considerable hardness and durability is now prepared by means of greater pressure and proper manipulation, the main object being to neutralize and extract the alkali, and to form a solid chemical compound by a second application of a weak wash of chloride of calcium or magnesium. The object is now fully achieved.

"Another important application of the soluble glass is to render wood non-inflammable, and stop any communication of the fire, and at the same time proof against water and damp. The wood, timber or other substances, after being boiled for several hours in the soluble glass, then exposed in tanks, containing solution of lime water and solutions of chloride calcium, are hereby petrified.

"Rail-road sleepers, cross-ties, house, ship and bridge timber will also be silicified by this process. Telegraph poles become more durable and better non-

conductors of electricity. The lining of barrels for oil and other liquids, the coating of tanks, tubs and cisterns, flour barrels, to prevent the flour getting musty, is very easily and effectually done by the proper and judicious use of the liquid silica.

"Soluble glass may be mixed with paper pulp, or cheap vegetable and animal fibre, and serve for the manufacture of a variety of useful articles, such as boxes, trunks, soles for boots and shoes, patterns, moulds and handles. *Invaluable and of the highest usefulness, the soluble glass can be employed in fire-proof paints, cements, varnishes, etc., for which purposes the daily demands are sufficient proofs.*

"The dentists make use of the silica for mending their plaster moulds, or in case of an accident to the cast of a set of teeth. Valuable documents are made fireproof, and parchment board, slates and marbles are cemented together, and cracks and crevices filled up.

"The woolgrowers apply the silicate of soda and potash to the greatest advantage for cleansing or degreasing the fleece wool and make it soft.

"The waste of wool or cotton used in the locomotive engines to sustain the lubricating materials, may be cleaned and made new by the aid of soluble glass.

"A hard and ornamental cement, which can be moulded like plaster of Paris, is obtained from the mixture of silicate of soda and ground dolomite or magnesian limestone, which may be used both natural and calcined in equal quantities, and before the mass is dry, the bittern (chloride of magnesium) from the salines is added, which will harden it at once. A good cellar and roofing cement is made by adding to this mass three parts of white sand.

"The silicate is also used for penetrating fire-brick and clay, in order to make them more fireproof, and also used for cementing the walls; for producing a durable putty in iron castings, such as furnaces, heaters, stoves, etc., and also for mending air-holes. Boiler makers can produce a very durable lining by making a cement of silicate with asbestos and manganese finely ground; it renders boilers and other metallic vessels perfectly fireproof, and the best fire and anti-rust paint for iron, steel and brass. There are a great many more useful applications in which the silicate may be used."

The alkaline silicates, as have been here described, have a bright future for their application: the genius of the nineteenth century cannot fail to accomplish the perfecting the work begun fifty years ago, and to this moment still liable to faults. Ere long we will be enabled to produce an artificial stone which shall excel nature; we will be able to produce a perfect silicification of wood and other organic matter; we will challenge the atmosphere and other chemical productions to do their best for forming a decomposition of those materials obtained by the new acquired skill to resist their action. The labors of Fuchs, Liebig, Kuhlmann, Vicat, Fremy, Guerin and Ransome have fairly begun their work, and in ten years more the shipbuilder, carpenter, mason, painter, the railroad contractor and the mechanic in general, will consider this valuable substance indispensable.

Among the most simple processes in the silicification or manufacture of artificial stone is that of Ransome, which consists in the following manner:

The sand, after being dried, is worked up in a mill with the soluble silicate prepared from caustic soda and flints, the latter being dissolved by the former, and evaporated down to a specific gravity of 1,700. The plastic mass thus produced is obedient to the will of the moulder, and can be manipulated into any form, from a cube to elaborate screens, from a grindstone to an exceedingly chiseled fountain. The mass so prepared is then saturated with chloride of calcium, applied simply by immersion or assisted by the action of an air-pump, in either process the solution being gradually heated to a temperature of 212° F.

The indurating action of the chloride of calcium is promoted in closed chambers connected with a steam boiler. When this has been carried on for a sufficient length of time, by opening a cock the solution is forced by steam pressure into a separate chamber, leaving the stone to cool gradually in partial vapor, by which all danger of cracking is avoided; a casualty which is liable to happen when large masses are exposed to rapid extremes of temperature in the open air. In order to remove or extract the soluble salts of calcium and sodium from the body of the stone, which is effected in the same closed chambers by the admission of steam, or steam and water alternately, which, as it condenses and becomes saturated with the salts referred to, is returned into the boiler, where the steam is generated, and the chloride of calcium is again made available for future operations, thus obviating the serious loss incurred by washing the stone in the way hitherto adopted.

Mr. R. was led to his last experiments from the

many faults which he discovered in manipulating; he supposed, at first, that by mixing sand and fragments of stone with the fluid silicate into a kind of paste and exposing them to the air, they would be permanently solid. But he found that stones they made very soon became disintegrated in any moist atmosphere, and particularly in England, and could never indurate. To remove this serious objection, he subjected them to the action of heat in a kiln, and he found then that at a bright red the cementing material or silicate parted with some of its free alkali, the portion thus renewed combining with some of the sand to produce an insoluble glass, unaffected by exposure to any of the acids present in the air, and not cracking by exposure to frost when damp. This artificial stone could be made so porous as to be well adapted for filtering slabs, or it could be so compacted by mechanical pressure before burning as to yield a material not inferior in its power to resist atmospheric action and even absorption. Paving slabs, garden vases, balusters, tombstones and various architectural fixtures, often constructed of terra cotta, were produced of superior quality and greater durability. The stone thus made, however, after some exposure, was found to become unsightly, owing to the efflorescence of the saline matter.

This patent siliceous stone was also found too expensive to come into general use on a large scale, but the inventor has, at last, succeeded in reaching to a satisfactory result.

The author has, many years ago in the course of his experiments, succeeded in preparing an artificial stone in the following manner:—Fluorspar, finely

ground, is mixed with the powdered soluble glass, 2 parts of the first to 1 part of the latter, the mixture made into a thin paste by the concentrated liquid soluble glass, and then as much finely powdered shell limestone, or magnesian limestone added, until the mass becomes thick enough to form into moulds or blocks, whichever may be desired; after an exposure of three to four days to the atmosphere, are treated by a weak solution of chloride of calcium, (2 pounds dry chloride to the gallon of hot water,) this liquid will soon be absorbed by the stone; it is then exposed again to the atmosphere for a week; a dilute hydro-fluoric acid is then applied with a sponge, and again exposed to the atmosphere; after a lapse of a week the stone is as hard as a natural stone, and not liable to crack or to disintegrate.

This composition is much easier prepared, and instead of common lime, chalk may be substituted, and the result is still more favorable. Instead of the entire quantity of lime, coarse sand may be partially added, and after the stones are moulded, are exposed to hydraulic pressure, and then exposed to the air, previous to which the chloride of calcium has to be thrown over it. The price of hydro-fluoric acid, as is used for this purpose, costs about 25 cents per pound, and this suffices for ten square feet.

Furthermore it may be remarked, that exposing the stone so prepared may be subjected to a high temperature or not; it may be left to the operator to decide whether it will improve the stone by this manipulation.

For the sandstone imitation, when 1 part liquid soluble glass is to be mixed with 2 parts powdered

soluble glass, and 15 parts of sand is added, it is necessary to expose the mass to great pressure, but requires not the addition of chloride of calcium, while exposure to great heat is indispensable.

An artificial stone may be also obtained by the use of the alkaline silicates with common chalk, which, by mixing even cold with the liquid silica, is at once converted into silicate of lime and carbonate of soda or potash; this composition, when exposed to the air, becomes in a few days hard enough so as to resemble a hydraulic lime, to adhere, when wetted again, like a cement, which may be used for restoring cracks and crevices in marble works and monuments.

The silicification of chalk has led to numerous experiments, and resulted in the production of artificial stone, in the formation of hydraulic lime, hydraulic mortar and the various cements. The first successful result of the treatment of chalk with the silicate solution has shown that the hardening of the chalk extended to the depth of four inches, which not alone was produced from the decomposition of the silicate by the carbonate of lime, (chalk,) but also by the carbonic acid of the atmosphere. If two balls of chalk of equal size and quality are silicified at the same time, and one of them is exposed to the atmosphere, the other kept under a bell glass, where the carbonic acid of the atmosphere is withdrawn, the first will acquire more hardness than the other, which proves that the silicification has assumed a hydrate of silico—carbonate of lime—which loses by degrees its water of crystalization, and forming a precipitate of silica, contributing mainly to the hardening of the stone.

A *hydraulic lime* may be obtained by the mixture

of a fat or rich limestone combined with soluble glass in a dry state, say 10 parts silicate to 100 parts of air lime, both fine powder, which proves plainly the theory of the part which the silicates play in the production of the native limestone, the artificial hydraulic lime, mortar, cements, and the application of all silicates for the purposes of building, production of artificial stones, and the conversion of organic into inorganic materials, as we shall show hereafter.

Wagner's report on soluble glass is in the following lines:

Soluble glass, called also water glass, liquid quartz, liquid silex, silicate of soda or potash, was accidentally discovered by the late Professor Fuchs, of Munich, in the year 1818, in the course of some investigations he was making for the preparation of pure silica. He became more familiar with its properties in 1820, and learned how to prepare it by the solution of silica in caustic potash. Afterward he studied the subject thoroughly, and became acquainted with all its properties and uses. In the year 1823, as the theatre in Munich, which had been destroyed by fire, entailing great loss of life and property, was rebuilding, the Government requested a scientific commission to search for an agent that would render the wood-work and stage materials incombustible. Professor Fuchs, in association with Doctor Pettenkofer, at once instituted numerous experiments upon soluble glass as the best agent for this purpose, and the conclusions at which they arrived have been fully confirmed by the subsequent studies and experience of other men. In

1826 soluble glass was manufactured in Augsburg on a large scale, and sold at the rate of 25 florins the 110 pounds. From this time forward a knowledge of the new compound became disseminated, and new uses were constantly suggested for it.

According to Professor Fuchs, there are four kinds of soluble glass:

1. Potash glass.
2. Soda glass.
3. Potash and soda glass (combined.)
4. Glazing glass.

Potash soluble glass is prepared by fusing together:

45 pounds of quartz,
30 pounds of potash,
3 pounds of charcoal in powder, and digesting the fused and pulverized mass in water.

Soda soluble is composed of:

45 pounds quartz,
23 pounds calcined soda,
3 pounds charcoal;

Or, according to Buchner, more economically of:

100 pounds quartz,
60 pounds calcined glauber salt,
15 to 20 pounds coal.

There are several ways of making the third variety of combined soda and potash soluble glass. By fusing seignette salt (tartrate of potash and soda) with quartz; by employing equal equivalents of nitre or Chili saltpetre and quartz; fusing cream of tartar, Chili nitre and quartz; or by melting at once:

100 pounds quartz,
28 pounds purified potash,
22 pounds calcined soda,
6 pounds charcoal powder.

For technical application it is possible to mix three volumes of a concentrated potash glass solution and two volumes of a soda glass solution.

The fourth variety, called glazing or fixing glass, is made by mixing perfectly saturated potash glass with soda glass, and is used for producing fast colors in stereochromy or fresco painting.

There is also a wet way for the manufacture of soluble glass, which consists in dissolving flint stones in concentrated soda lye in iron boilers under 7 or 8 atmospheres of pressure, and for this purpose infusorial silica or tripoli is also specially adapted. The tripoli is first calcined to destroy all organic matter, and then introduced into boiling soda lye of 1.5 specific gravity, or potash lye of 1.135, and afterward clarified by a little water lime and evaporated to the required consistency. As soluble glass readily absorbs carbonic acid, it must be kept in closely stopped packages. The strength of the solution is estimated in degrees founded upon the package of dry powder dissolved in the water; 33° means 33 parts dry glass and 67 parts water; 40° = 60 parts water and 40 parts soluble glass. In applying the solution to wood-work, roofs, fabrics, porous stones, &c., it is necessary to begin with a weak solution and to wait until it is thoroughly dry before putting on a second coat. The second application can be considerably more concentrated than the first. It will not adhere to freshly painted

surfaces, but when the oil is thoroughly dry and changed in the sun light, the water glass can be used with impunity. Care must be observed to wash out the brush thoroughly after use to prevent its hardening to stone. Soluble glass protects wood from the influence of fire, water and the atmosphere. The surface of wood is covered with glass, and not only will not take fire, but is less liable to decay. Some varieties of wood are apt to be discolored by the solution; oak and beech are the least affected. As the soluble glass when applied to wood serves a purpose analogous to a varnished surface, it is necessary to avoid a too concentrated liquid, as otherwise it is liable to scale off. One pound of 33° solution, diluted with five pounds of water, is found to cover wood very well. Wood, paper, linen and straw, when covered with several coats of soluble glass, are no longer inflammable, but simply char when exposed to fire. A coating of glass also prevents the decay and rotting of wood, and keeps out worms. Beer barrels, butter firkins and milk tubs can be easily kept clean when painted with soluble glass, and the same is true of vessels designed to hold sugars, syrups, wines, petroleum, &c. The most important use of soluble glass is its application to surfaces of stone and mortar. For this purpose it is necessary to impregnate the surface with a solution composed of one part 33° and three parts rain water. For this purpose a powerful pump or syringe, with a spout like a watering-pot, is used for injecting the liquid, in the form of syrup, into the pores of the stone or mortar. The surfaces thus prepared are in condition to receive the further coating of liquid quartz.

Mortar and porous limestones react upon the soluble glass, producing carbonate of lime, hydrate of lime, and, ultimately, silicate of lime, which thus presents an impervious, vitreous surface, capable of resisting the action of moisture and the atmosphere, and is in a proper state for fresco painting in mineral colors. Organic colors are apt to be destroyed by the alkali of the soluble glass, and hence, for fresco painting, mineral paints are alone available. A second coating of paint, rubbed up with soluble glass, is usually sufficient for all practical purposes, and a wall thus treated can be washed with soap and water, and kept thoroughly clean. A plain, white color is obtained by mixing chalk with soluble glass. Zinc white, and silicate of soda set so rapidly, that it is necessary to add $\frac{1}{4}$ to $\frac{1}{2}$ its weight of precipitated sulphate of baryta before applying the color. Baryta white and soluble glass also afford a good, fast color. Fluor spar, with pulverized glass and soluble glass, also gives an exceedingly solid mass. The pigments that have been found by experience to serve the best purpose are chromate of zinc, sulphate of cadmium, blue and green ultramarine, Schweinfurth green, oxide of chromium, cinnabar, &c. Prussian blue and colors prepared from it, and chromate of lead, will not answer, as they are destroyed by the alkali, the same as organic colors. It is well known that the fresco painting in the capital at Washington, in the new museums in Berlin and Munich, are done with water glass, and that the success in their use is complete.

Soluble glass, with or without colors, adheres closely to such metals as iron, zinc and brass, and protects them from the influences of the air and water. It has

been found that when stoves are painted with a mixture of soluble glass and black oxide of manganese, a species of flux is produced by the heat which does not scale off, but thoroughly protects the iron from any corroding action. Plate glass, when coated with the soluble silicate, becomes opaque, and when baryta is mixed with the liquid quartz, it assumes a fine, white appearance. If the glass be heated it becomes enameled, like porcelain; and fixed colors, such as ultramarine and oxide of chromium, open up an extensive application for soluble glass for transparencies, church windows, &c. The manufacture of artificial building stone by means of soluble glass has been conducted in Germany and England on an extensive scale. In Vienna barracks of an enormous size have been constructed of such artificial stone; and the tower of the Cathedral in that city was put into thorough repair in the only way that was possible, considering the great height of the tower and the extent to which it had fallen to decay.

When ground chalk or marble is stirred into a paste with soluble glass, the mass becomes so hard that it can be employed for building purposes, or for the restoration of decayed stone structures.

Marble and dolomite immersed in a solution of soluble glass, and the operation repeated a number of times, take up an appreciable quantity of silica, and become so hard that they are capable of taking a fine polish. Attempts to employ such stones for lithography have been made, but not altogether with success. Artificial stone can be prepared as follows:

Well washed and gently heated sand is stirred into a warm solution of soluble glass until a proper con-

sistence has been reached for pouring it into a mould. After it has set it is removed from the frame, which ought to have been previously oiled, and is left to dry in an airy place. To avoid too great a consumption of water glass, a stone or brick can be put in the centre of the mould. It is also possible to stir in pebbles and to use earthy colors in imitation of marble and conglomerate. Such artificial material becomes very hard, and is adapted to pavements, hearths and building purposes.

Soluble glass can be used in the manufacture of paper hangings, for printing on paper and woven fabrics, for attaching gold and silver powder to any kind of object.

Hydraulic lime can be prepared by mixing in fine powder 10 to 12 parts by weight of dry soluble glass and 100 parts of lime—this affords a ready way of preparing a hydraulic cement from ordinary lime, which is always available.

One of the earliest and best known uses of soluble glass is as a cement for glass, porcelain and metals. It is put up in small packages for this purpose, and sold on the corners of streets under various names. Pieces of glass or porcelain cemented in this way will break more readily in places which were whole, than where they were repaired. The solution ought to be quite concentrated when employed for this purpose. The fragments to be repaired must be heated to the boiling point of water, and both surfaces be then moistened with the cement and pressed closely together, and held in position by a strong cord, and left to dry in a warm place. By mixing sulphate of magnesia or calcined magnesia and soluble glass, a cement

can be formed that can be cast into moulds, and very generally be substituted for meerschaum.

Soluble glass has been used in restoring several European churches, also the Houses of Parliament in London.

Wood and timber and other porous substances, after being boiled for several hours in soluble glass, then exposed in tanks containing lime water or chloride of calcium, and left to dry, become highly vitrified and incombustible. Rail-road ties, ships' timber, house and bridge beams, have been treated in this manner with entire success.

The silicate is also used for penetrating fire brick and clay, and for cementing the walls of furnaces.

When stirred up with chloride of calcium and used for luting down the covers of crucibles, it answers an excellent purpose.

HYDRAULIC LIMESTONE, CEMENTS AND PLASTERS.

It is necessary to explain the main material used in building, which is lime, before we can proceed further with our subject of silicification, or imitation of the same substances by means of art, latterly acquired, and which bids fair to excel nature. From one of Ansted's lectures on practical geology, the following article on cements and plasters gives a good idea of their importance:

"The earliest architectural constructions to fasten together the bricks or stones of which buildings are made were of various kinds; the most common is called *mortar*. It is obtained by first calcining crude limestone in a kiln, and converting it into quicklime, by depriving it of its carbonic acid. After calcining, the resulting quicklime is of a whitish or grayish powdery and cracked substance, which, on the application of water, absorbs a certain quantity with the evolution of much heat, and crumbles into a fine powder. This powder, further moistened, made into a thin paste with water, and mixed with two or three times its own weight of sharp sand, is called *mortar*. Slaked lime, or hydrate of lime, as moistened quicklime is called, absorbs carbonic acid from the air, and in time mortar is reconverted into limestone; but the operation goes on under peculiar conditions, and the result

is also peculiar; for a film of silicate of lime is formed round each grain of sand, and thus the whole mass and the stones, between which it is placed, become in time more compact than the particles of limestone.

"As, however, there are different kinds of limestone, more or less impure, the result will be limes of very different qualities and properties. These require special treatment to obtain from them the best results. The purest carbonate of lime, such as marble, or chalk, make what is called a rich lime, setting firmly only in dry air, while the very impure carbonates, in which clay is largely mixed with the limestone, result in the production of hydraulic limes, which set more or less rapidly in moist air or even under water. Some of the impure limestones are used in the manufacture of cements by the admixture of definite proportions of foreign ingredients. Sometimes, by the admixture of certain substances (as puzzuolana) with the rich limes, instead of sand, hydraulic limes are produced. There are few subjects connected with the application of geology that are more important, than the determination of the material that should be used and the treatment adopted in various countries in the manufacture of cements, mortars and stuccoes.

"Commencing with nearly pure carbonates of lime, it is not difficult to trace the changes that take place in their conversion into cements; a layer of such mortar, not too thick, placed between bricks or stone, which are themselves absorbent, and kept in dry air, dries gradually and holds together such substances with extraordinary tenacity. But this is a work of years, and sometimes even centuries must run out

before the extreme of hardness is attained! It is not unusual to find imperfectly hardened mortars in very old constructions. The mortar that fastened together the bricks in the old Roman walls is now almost everywhere so far hardened that a fracture takes place in the brick rather than in the cement.

"Limestone is widely distributed, and almost every variety, however impure, can be burnt into lime. In the manufacture of good common mortar to set in the air, pure limestones and those of fair ordinary quality are available; but in using them, attention must be given to their composition and even texture; thus, the hardest limestones and marbles make the fattest lime, but each variety yields a lime of different quality, distinct in color, in weight, in the greediness with which it absorbs water, and in its ultimate hardness. The method of calcination also varies, but the general result is that, after burning the limestone, the resulting quicklime is lighter than the original stone, and differs from it essentially. To determine the nature of lime and its peculiar properties, perfectly fresh samples should be placed in a small open basket and immersed in pure water for five or six seconds; removed from the water, the loose, unabsorbed water must be allowed to run off, and the contents of the basket emptied into a stone or iron mortar. According to the nature of the limestone, the lime will now exhibit some one of the following phenomena:

"1. It will hiss, crackle, swell, give off much vapor, and fall into powder instantly.

"2. It will remain inert for some short time, not

exceeding five or six minutes, after which the results stated in (1) will be energetically declared.

"3. It will remain inert for more than five minutes, sometimes extending to a quarter of an hour; it then gives off vapors to a moderate extent, and cracks without noise and without much evolution of heat.

"4. The lime will crack without noise and with little steam, but not until an hour has elapsed.

"5. The lime will become scarcely warm to the touch, will not fall to powder, and will crack to a very small extent.

"In each case, before the effervescence (if any takes place) has quite disappeared, the slaking should be completed by the addition of water, not thrown upon the lime, but by the side of it, and the result should be frequently stirred, more water be added, till the whole is brought to the consistence of thick paste. When the mass has cooled, which will not take place for two or three hours, the whole should be beaten up again, until a firm but tenaceous paste is produced, resembling clay prepared for pottery manufacture. Vessels being then filled with this paste, or obtained from each variety of limestone, the day and hour of immersion should be marked upon them, after which they are left to solidify.

"We thus obtain a test of the nature of the materials used, which may belong to one of five classes:

(1.) Rich limes.
(2.) Poor limes.
(3.) Moderately hydraulic limes.
(4.) Hydraulic limes.
(5.) Eminently hydraulic limes.

"The word hydraulic, as applied to lime, means only, that it possesses the property of setting, or becoming solid, in moist air or under water.

"Rich limes are obtained from the purest and hardest limestones. When slaked, they increase to double their volume; if employed alone, they remain unaltered even for years, and they are soluble in pure water. Limestones which contain from 1 to 6 per cent. of foreign substances, such as silica, alumina, magnesia, &c., yield rich limes; but such as contain from 15 to 30 per cent., are poor limes; they increase in bulk, but little on slaking, do not set under water, and are soluble, like the rich limes, except that they leave a residuum. The fossiliferous limestones make bad mortar, as the slaking is irregular; limestones containing much silica swell in setting, and may dislocate the masonry executed with them. Where alumina is in excess, the lime is apt to shrink and crack. Where carbonate of magnesia is combined with carbonate of lime, as in the magnesian limestones, the original bulk is retained. For ordinary purposes, moderately pure limestones, with a mixture of foreign substances, is a moderately pure limestone. Hydraulic limes are of great value in construction, and are extremely interesting, and are either obtained naturally from the burning of certain varieties of calcareous rock, or are manufactured artificially by mixing limestones with the requisite foreign ingredients; such are the Roman cement, Portland cement, Parker's and Rosendale cements. The Portland cement is largely manufactured at the mouth of the Thames from a mixed river mud, while Roman cement is

formed from the nodules found in the cliffs near Harwich, all owing their quality to argillaceous admixture. Limestone, containing from 15 to 25 per cent. of a silicate of alumina, will burn into a good hydraulic lime. It is also quite certain that the oxide of iron and carbonate of magnesia exercise a great influence in rendering limes more hydraulic. All materials intended for the manufacture of cements require to be burnt carefully, and ground down to a fine powder, and the best cement is the lightest. When these cements are intended for the production of an artificial stone, from ten to twelve times the weight of broken stones and pebbles are added, and form also an excellent *concrete*. A stone made from these cements just described, will bear a strain varying from 20–60 pounds to the square inch.

"The plaster cement is obtained from the gypsum, or sulphate of lime, abundant in England, France and the United States; is treated like common limestone for a cement. The calcining of gypsum does not involve its decomposition, but the water of solidification being driven off by the calcination, leaves only a soft white powder called plaster of Paris; when this is again united with water, the latter is absorbed, and the mass becomes first, plastic, and then solid; but it cannot be brought back to its original condition as a crystaline mineral, but it is converted into various substances used as cement, such as *Keene's* cement, if alum is added to the fine powdered plaster; parian cement, if borax is used; Martin's cement, if pearl ashes are employed. *Stucco* is a very useful material for ornaments for in and out-door work, is nothing

else but a plaster of Paris, finely ground, and a weak glue added before mixing it with water.

"One of the richest kinds of hydraulic lime may be obtained from volcanic minerals mixed with limes; such material is the Puzzuolana, found near Naples, as well as other substances found in large quantities in the neighborhood of extinct volcanic districts, as in France and on the Rhine; and which, according to its chemical analysis, consists of 44 per cent. of silica, 15 per cent. alumina, 87 per cent. lime, 4 per cent. magnesia, and 12 per cent. oxide of iron; combined with lime instead of sand, have the property of rendering even the richest limes hydraulic, and fit for use for every description of works executed in the sea or in fresh water; they have been used from time immemorial with great success, and may be mixed either with fat or hydraulic limes and silicate of soda to form a plastic mass, and assist in the setting of the lime.

"In regard to hydraulic cements, Frémy says that the setting of cements is due to two different chemical actions: 1. To the hydration of the aluminates of lime, and 2. To puzzuolanic action, in which the hydrates of lime combine with the silicates of lime and alumina. He found that alumina is even a better flux for lime than silica, and he suggests that the very basic compounds of these two substances, those, for instance, containing from 80 to 90 per cent. of lime, may be useful in the iron furnace for absorbing sulphur and phosphorus, and free the metal from those noxious impurities; and he finds that no substance is capable of acting as a puzzuolana except the simple or double silicates of lime, containing only from 30–40 per cent. silicate, and sufficiently basic to form a gelatinous pre-

cipitate with acid; and he confirms Vicat's theory, that the cause of the setting of hydraulic cements was owing to the formation of a double silicate of alumina and lime absorbing waters, forming hydrates and causing the setting of the materials.

" Theory of Hydraulicity.

" Frémy has lately published his researches on hydraulic cements, and in giving the theory of their hydraulicity, he rejects the commonly received opinion that the setting of hydraulic cement is due to the hydration of the silicate of lime or that of double silicate of alumina and lime. These salts form no combination whatever. He attributes the setting of hydraulic lime to two chemical actions: 1st. To the hydration of the aluminate of lime; 2d. To the reaction of hydrate of lime upon the silicate of lime, and the silicate of alumina and lime which exist in all cements, and in this case act as puzzuolanas.

" The calcination of the argillaceous limestone produces good hydraulic cement only when the proportions of clay and lime are such that they form, in the first place, an aluminate of lime, represented by one of the following formulæ: $Al\ O_3$, $Ca\ O$—Al_2, O_3, $2\ Ca\ O$;—Al_2, O_3, $3\ Ca\ O$; in the second place a very simple or multiple silicate of lime, which gelatinizes with acids, and approximates to the following formulæ:—$Si\ O_3$, $2\ Ca\ O$—$Si\ O_3$, $3\ Ca\ O$; and thirdly, free lime, which may act upon the preceding puzzuolanic silicates.

" In many cases the chemical composition of an argillaceous limestone is not only the condition which

determines the quality of the cement; the reaction of the lime upon the clay must take place at the highest temperature. Indeed, this excessive heat produces the hydraulic elements of the cement in the basic conditions which the setting in the water requires, and which, by melting the aluminate of lime, gives it all its activity.

"HYDRAULICITY OF MAGNESIA HYDRATES.

"Since the publication of Frémy's paper, Deville has read a note before the Academy of Sciences, 'On the Hydraulicity of Magnesia,' in which he alludes to a specimen of magnesia prepared by the calcination of the chloride sent to him, seven years before, by M. Donny. A portion of it was left under the tap of his laboratory, constantly exposed to running water. In time it took a remarkable consistence, became hard enough to scratch marble, and was clear as alabaster. After six years exposure to the air, it has not perceptibly changed, and its analysis gave the following results: Water, 27.7 per cent.; carbonic acid, 8.3; alumina and oxide of iron, 1.3; magnesia, 57.1; sand, 5.6. Total, 100.

"Thus the substance appeared to be essentially a crystalized hydrate of magnesia, like brucite, which does not absorb carbonic acid. To prove that it was really so, M. Deville prepared magnesia by calcining the nitrate, powdered it, made it into a plastic mass, and sealed in a tube with some boiled distilled water. After some weeks the mass became as hard and compact as the other, and also crystaline and translucid. After drying in the air, this mass was found to con-

sist of 30.7 per cent. water, and 69.3 per cent. magnesia, showing it to be a simple hydrate of magnesia. With similar hydrate, cast of medals were taken, which, on being placed in water, assumed the appearance of marble.

" M. Balard's magnesia, prepared by calcining the chloride, obtained by treatment of sea water, when brought to a red heat shows astonishing hydraulic qualities, which are partially destroyed by calcining at a white heat. A mixture of chalk or marble and magnesia, in equal parts, forms a plastic mass, which, placed under water for some time, becomes hydrated and extremely hard.

" An average sample of Portland cement will yield, upon analysis, in one hundred parts: Lime, fifty-five; iron, seven; alumina, eight; silica, twenty-four; potash and soda, three; sand, two; water, one. The essential constituents are the lime, alumina and silica."

The author delivered a discourse on cements before the Polytechnic Association, 20th April, 1866, of which the following is the substance:

" Cements.

" The subject for the evening—cements—was here taken up, when Dr. Lewis Feuchtwanger exhibited a number of minerals used in different kinds of cements, and read the following paper:

" ' The meaning of cement is, a paste used for uniting solid surfaces without always forming a combination with the constituents of either surface. Many cements contain pulverulent substances which are mingled with a glutinous or very adhesive material,

and do not combine chemically; others again form chemical combinations. Furthermore, many substances are capable of assuming a liquid or semi-fluid form, and are thus applied between the surfaces of bodies which are firmly united when the fluid has solidified.

"'The most common cements are mortar and hydraulic cement. We have also lutes and fire cements; but as it is important to ascertain the best mode of obtaining a good hydraulic cement, that is, a cement which hardens under water, I will at once take up this branch of the subject, premising, however, that common mortar is simply a mixture of lime, water and sand, the best proportions being one cubic foot of fresh burnt lime, weighing about thirty-five pounds, and three and one-half cubic feet of good river sand, not round, but angular; these, with one and one-half cubic feet of water, produce about three and one-half cubic feet of good mortar.

"'Hydraulic or Roman cement is composed of certain proportions of lime, sand, clay and water; after it has been applied a few days, and placed under water, it becomes very hard and like stone. We now find walls and piers which are known to have been built more than a hundred years ago, and have been exposed under water, to have remained as solid as iron. The name Roman cement is derived from the district of Puzzuoli, near Naples, where the natural material, the tufas and puzzuolanas, are in great abundance. The Pontine marshes around Rome and the volcanic tufas near Naples have always afforded a natural cement, for they are composed of silica, alumina and lime. Besides these tufas, many marls, belonging to the sedimentary rocks, are used as hydraulic cement.

The cement stones, allied to the oolitic formation, and found in argillaceous strata alternating with limestone beds, and of very curious nodular and lenticular forms and concretions, on the English and French coasts, and in this country the septaria, toadstones, ludus helmontii of various sizes, and consisting of siliceous clay and lime strata interwoven, yield the proper material for hydraulic cement. All these marls contain, according to analysis, about seventy per cent. of carbonate of lime, twenty per cent. of silica, and twenty per cent. of clay; and the lime when calcined becomes caustic, and, in combination with silica, forms, under water, a chemical compound, as a hydrated silicate of lime; and, by the presence of clay, which is a silicate of alumina, forms double silicates of greater solidity. $Ca\ O—CO_2—Si\ O_3—Al_2\ O_3$.

"'The Roman or hydraulic cement mostly contains, also, magnesia and iron; whether of any essential benefit or not, has not been fairly tested. It is certain that neither of these substances exercise a pernicious influence, for the reason that dolomite, a magnesian limestone found in great abundance in this country, offers a fine material when calcined with any marls, so abundant along our coast. It produces an excellent hydraulic cement.

"'The analysis of the hydraulic lime from Rondout, on the North River, gives in one hundred parts:

Carbonic acid,	35	Lime,	26
Magnesia,	12	Silica,	15
Alumina,	10	Iron,	2

"'Sand or quartz, which by itself is unfit for a mortar, when calcined with lime, becomes very suit-

able for a hydraulic cement or artificial stone, for it forms a silicate of lime. More than thirty years ago, I entertained the idea of preserving timber by the infiltration of silicate of lime into the cells of planks, timber, and through the double chemical affinity of silicate of soda and sulphate of lime. The experiments I made then, in the Brooklyn Navy Yard, with pier piles and wooden vats, were very satisfactory.

"'For water-proofing cellars and buildings, not alone the best hydraulic, but other cements have of late years been introduced in this city; for instance, the asphalt cement, which is very extensively employed in the foundation of buildings. Having made, myself, many experiments, for a number of years past, in order to introduce the silica cement, or the soluble glass in combination with alkaline earths as a base, and met with varied success, I beg to offer here a sample of a cement which consists of silicate of lime combined with manganese and fluorspar, or fluoride of calcium, which becomes very hard, and which, I think, will, after some improvement in the preparation, be found highly useful in keeping dry walls and cellars. I have mixed equal quantities of manganese, limestone, fluorspar and dry soluble glass, and make the whole mass plastic by the liquid soluble glass, and apply it while soft; after the lapse of a few hours it becomes very hard.

"'Fire cements are lutes, for crevices and joints, which are intended to be used for furnaces, iron pipes and retorts exposed to constant red and white heat; or for joining gas and water pipes, and many other substances, may, if judiciously applied, prove very acceptable. I beg to offer a few which I consider useful:

"'No. 1. *Iron Cement or Lute.*—Brick dust and fire clay in equal parts, borax, red lead and sal ammoniac, one-tenth of the other ingredients; cast iron turnings. The whole mixture made up with water so as to knead them together, and spread it in layers. It is suitable for crevices or joints of iron pipes, furnace doors, man holes of boilers, etc.

"'No. 2. *A Steam-resisting Cement.*—Two parts litharge, one part sand, one part slaked lime; made plastic with hot glue.

"'No. 3. *An Iron Cement.*—Manganese twenty-four parts, red lead five parts; formed into a paste with linseed oil.

"'No. 4. *Cement for Fastening Iron and Stone.*—Calcined plaster, iron filings and hot glue.

The three following are good cements for cisterns, etc.:

"'1st. Ten parts of plaster of Paris, two of Glauber salts, four of clay, and four of lime.

"'2d. Twenty-two parts of clay, nine of iron filings, sixty-three of lime, one of magnesia, one of pearl ash and ten of charcoal.

"'3d. Thirty parts of sand, seventy of lime, three of litharge, made up with linseed oil.

"'A very remarkable cement for almost any substance is made in the following manner: Either glue or gelatine is swelled up in water and then immersed in linseed oil and heated. It dissolves and forms a paste of great tenacity, which, when dry, resists dampness perfectly. Two pieces of wood joined by it may separate anywhere except at the joint.

"'The china or diamond cement, for joining glass or china ware, consists of gum mastic and ammonia dissolved in alcohol, to which is added hot glue. Spalding's glue is the old Berzelius paste, that is, glue dissolved in acetic acid. The Japanese cement is rice flour made into a paste and dried.

"'In 1841, a patent for a lime cement was obtained by Kuhlmann, who adds an alkali, like soda or potash, before calcining the limestone with sand and clay, so as to produce a soluble silicate with the ingredients of hydraulic cement.

"'The Portland stone or cement, so extensively used in England, and exported largely from there to all parts of the globe, and forming the base of many patent cements, such as Reese's and others, is nothing but powdered oolite, a mineral lime deposit. Hamelin's mastic cement, another very celebrated cement, is prepared from sixty-two parts of oolite, thirty-five of sand, and three of litharge.

"'The celebrated French cement of Bouilly is said to be prepared from the Boulogne pebbles, called golets, which are marly nodules of all sizes, like the septarias and marly concretions of other countries. A number of years ago I prepared a good hydraulic cement from one part of the poorest limestone, one of clay and three of sand. I also prepared a terra cotta, which is likewise a cement, composed of clay and sand, slowly dried and calcined.

"'Among the great variety of cements in which silica is the active principal, the two following are very useful:

"'1. A mortar, to be made as hard as any cement,

and which does not crack in setting, and even of great usefulness as hydraulic cement under water, is obtained by mixing finely slaked lime with fine sand (the angular grains are always preferable to the round grains for producing a good mortar.) By mixing the sand thus prepared with finely powdered quicklime, and stir the mixture thoroughly. During the process the mass heats, and may then be employed as mortar, to which has to be added to one-eighth of the mass the liquid silicate of soda.

" ' One part of good slaked lime was used with three parts of sand, and to this was added three-fourths of its weight of finely powdered quicklime; the mortar containing one-eighth of the liquid silicate of soda was then used as a foundation wall, and in four days had become so hard that a piece of sharp iron would not attack it; and in two months afterwards it had become as hard as the stones of the wall.

" ' 2. A thin coating of slaked lime made into paste with water or whitewash is put at once on the stone, and before becoming quite dry apply the silicate solution over the paste, by which the mass becomes completely insoluble; a petrification takes place if applied to vegetable substances, decomposition is prevented, porous building stone and brick are protected against air and damp.

" ' Common Mortar.

" ' Limestone, an impure carbonate of lime, when exposed to a red heat, loses carbonic acid gas, and the oxide of calcium or lime remains. This process of burning lime, as it is called, is accelerated by the

presence of moisture in the stone, or by the introduction of a small quantity of steam into the lime kiln. The hydrate of lime reacts with considerable power on siliceous compounds, but the action only takes place at the surfaces, and unless the lime is used in very thin layers, between smooth stones, it still retains, in the centre of the layer, its own soft and friable condition.

" 'In order to make the hydrate of lime effective as a cement, it is mixed with sand, one of the most abundant of natural compounds, now regarded as consisting of two atoms of oxygen and one of silicon. Equal parts of fine and coarse sand are said to be better than either quality used separately with lime. Mortar designed for exterior or surface work is generally made with fine sand. When lime is comparatively free from impurities, and crumbles to a fine powder on being slaked, it is called fat lime, and will require about six times its own weight of sand, or, if estimated by bulk, one cubic foot of semi-fluid lime and water, called the milk of lime, will require about three or four cubic feet of sand. This mortar is very effective as a cement when well dried or set, but if it is placed in water, the lime is gradually dissolved and the mass is disintegrated.

" 'Hydraulic Cement.

" 'For all permanent structures under water it is, therefore, essential to use a material called hydraulic cement, which is a mixture of lime with other oxides possessing the valuable quality of hardening until it has the solidity and permanency of the masses of rock

bound together by it. The varieties of limestone from which hydraulic cement is made, when burned, yield a lime that is very slowly slaked. All that is required is to add water until it attains the consistency of dough; it will then harden and become concrete. These hydraulic limes may be made artificially by mixing with impure slaked lime a quantity of burnt clay in the proper proportions. The celebrated Roman cement is a porous volcanic rock found at Puzzuoli, near Naples, and called there puzzuolana. It consists of silicate of alumina, soda and lime. This substance is pulverized and mixed with common lime.' "

The Silicate Hydraulic Cement in the Prevention of Wall-Damp.

In laying the foundation of any building, the matter of particular consideration should be the thorough drainage of the site, and next to that complete prevention of wall-damp, that is, the rising of moisture by capillary attraction or otherwise, in the heart of the brick or stone work, the particulars of which have been lately described in the *Manufacturer and Builder's Journal*, to which the author had added the silicification of the bricks and plaster. It states that wherever brickwork comes in contact with the earth, or even with adjacent walls which may happen to be damp, there the infection is certain to take, and there is no easy cure for it, if once it makes an entrance.

The readiest remedy in all cases is a layer of fine concrete, which may be thinly coated on the top with

asphaltum laid on hot. This done all around the top of the walls, external and internal, the piers and every piece of brickwork, that in any manner has connection with the ground, then the bricks, which ought to be specially prepared before calcination with a silicate solution, should be heated over charcoal furnaces and dipped in the asphaltum before being laid. It is evident that a preventive course could thus be formed above ground at a trifling expense, wholly impervious to wall-damp, at the same time giving a base to the superstructure of a quality very far superior to any now in use. Coating the outside face of the wall with water-proof silicated cement, as has been before noticed, is the only safeguard against capillary attraction from below, and excluding the external air which might let the artificial heat of the rooms to attract the enemy of wall-damp. It is known that common brick will absorb one-fifth of its weight of water, and where the storm drives the rain continually against the face of a wall for a sufficient time to permit the interior heat to attract it, the inside of the wall must, of necessity, be damp, and the papering become mouldy, as well as the ceiling, will next be rotten. This cause of wall-damp is one that cannot be too carefully guarded against, as it is one to which may be referred the early decay of many residences, as well as the inception of these pulmonary symptoms which so surely steal away the health and ultimately the life of many a victim.

The mortar to be used in the foundation and the wall ought to be very well prepared, so as to possess all the hydraulic properties and silicification, and caution should be taken in not using sea sand, which will

certainly create the damp by absorbing all the water in the atmosphere, this being the chemical effect of its saline property.

The surface of the walls of the rooms must be well attended to; the plaster of Paris, which is generally employed, ought to be properly silicified, so as to prevent the absorption of the natural damp of the atmosphere created in uninhabited and unheated rooms.

It is preferable to paint rooms than to paper them, for the white lead and linseed oil, with some manganese to facilitate the drying, becomes hard after a short time, and assists the fresh plaster wall in preventing the admission of the moisture, as the fourth coating of white lead is applied with equal proportions of oil and spirits of turpentine, which has the property of being very volatile, will evaporate entirely, leaving the surface of the paint of a very compact and hard nature, and rendering the plaster incapable of absorption.

Damp Walls and Cellars.

The application of silicates for preventing the penetration of rain or moisture in houses, whereby the walls are absorbing the same, and render the paper-hangings or delicate paint unfit, so as to destroy their appearance, has been amply and satisfactorily proved. The silicates of soda and potash, or either of them, are mixed with pure white lead or zinc, and applied soon after upon the walls, which will dry immediately.

The presence of damp in walls arises from three causes: either from the porous condition of the materials of which they are built, allowing the penetration of damp from without; from the existence of salts in

the mortar, bricks or stone, which absorb and give out moisture, according to the changes of the weather, or from damp foundations. The first only can be remedied by the application of external coatings, the second by battening the walls, and the last by removing the adjacent earth from the foundations.

As has already been stated, a single application of a paint formed with lead or zinc has proved very successful. The second application is the silicate solution with china clay, or pure alumina, which has the advantage of not drying so quick as that with lead or zinc. In all cases the paints must be put on uniformly, so that the whole wall surface should be completely covered with the solid coat; and in order to effect this, a rough stucco surface, from two to three coats, may be required. It is found also useful to apply the second coat thinner than the first.

The mixture of liquid silicate of soda with clay and that of whiting, or washed carbonate of lime, may probably be the most reliable for keeping out damp from walls as well as cellars.

On applying the lead or zinc as the first coat, either of them or both, it may be done in the following manner:

Mix them with a little water and lay them on the stone, they will dry very soon; apply then the silicate solution by means of a syringe. If the application is to be made on stone which shows some decay, it is necessary to remove first the same, apply then the aluminous silicate of soda, (by an equal mixture of liquid silicate with fine white clay,) and then apply the carbonate lime and silicate wash with an ordinary paint brush, stippling it so as to give it the appear-

ance of the granulated surface of the stone. When dry, it will adhere sufficiently to allow of other washes of silicates being brushed on it.

The conditions necessary for success are:

1. The wall should be coated with a porous material, such as lime or Portland cement.

2. The coating must be perfect. A wall which has been once painted is altogether unfit for any application of siliceous washes, for the reason that it is not absorbent enough.

The best ground for any siliceous work is lime and sand. In new buildings it would be better to use lime and sand at once, and then to cover it with lime and silicate of alumina and soda. The precipitated sulphate of baryta may safely be applied in the silicate of soda for all the above purposes, and it will produce a good coating and a fine paint.

Manufacture of Portland Cement.

Portland cement was introduced to public notice under a patent by an Englishman nearly fifty years ago, and a partial monopoly in its production has been kept up, inasmuch as inexhaustible beds of the raw material from which it is made, and an abundant supply of fuel necessary for their economical manufacture, is at hand. It is strange that under these conditions French engineers should have obtained the start of their professional *confreres*, and that they should have been the first to demonstrate by experiments, and subsequently by the erection of magnificent harbor works on their seaboard, the valuable properties of this

excellent constructive material. We may date the *extensive* employment of Portland cement in England from the commencement of the metropolitan main-drainage works. During the last fifteen years the manufacture of Portland cement has gone on steadily increasing, until at the present day we find that little short of 400,000 tons per annum are made in the county of Kent—the centre of cement manufacture—irrespective of the productions of many minor factories in different parts of the country.

The chemistry of the setting of Portland cement is by no means so well understood as it ought to be. There is no doubt, however, that, like the hydraulic lime and natural cements, it is, chemically speaking, a double silicate of lime and alumina; silicic acid is generated by the hydration of the cement, and forms insoluble salts with the lime and alumina bases. It is a curious fact that Portland cement hardens more rapidly when salt water is employed. According to Schweitzer, 1,000 grains of sea-water in the English Channel contains 27,060 grains of chloride of sodium; soluble silica has a known preference for alkaline bases, and it is not improbable, when the cement is hydrated with sea-water, that the chloride of sodium is decomposed, the silicic acid of the cement combining with the sodium and oxygen of the water, and forming thereby a silicate of soda, or a species of crude glass.

Portland cement is of two classes, which, for the sake of distinction, may be termed "Engineers'" cement and "Plasterers'" cement. The former is the more costly; it is usually described by manufacturers as "best heavy tested;" it weighs from 112 pounds to

120 pounds to the bushel, is slow setting, and of great strength; the latter is a light cement, quick setting, and of inferior strength when compared with the other. It must be understood that our remarks apply exclusively to "Engineers'" cement.

Portland cement is made from chalk and alluvial clay; the factories on the banks of the Thames use white chalk, those on the Medway gray chalk; the latter is probably preferable, inasmuch as it contains large quantities of silicious matter. Mr. Read, in his treatise on "Portland Cement," says that "the present and safest proportions, provided both chalk and clay are selected free from sand, are four parts of chalk from the Medway, (gray,) or three parts of Thames, (white,) with one of clay by measure." These materials are placed in mills of simple construction, each having a circular pan, 6 feet in diameter and 2 feet deep, in which two "edge runners," 4 feet 6 inches in diameter, are kept continually going; a constant stream of water flows into the pan, and as the "edge runners" revolve, the chalk and clay are thoroughly ground, and, being thus converted into a fluid state, they filter through a band of fine brass wire gauze fixed to the side of the pan, and flow through wooden "launders" into tanks or settling reservoirs. One washmill will feed four tanks, each of which is about 100 feet long, 40 feet broad and 4 feet deep. When one of these has been filled in the manner just described, the same process is applied to the others in succession. About three weeks after the tanks are filled, the whole of the materials will be precipitated, the clear water being drained off in the meantime through a small weir in the brick side of the tank; the residuum is a plastic

mixture of the consistency of "putty," and not much unlike it in color. The next process is to convey this precipitate from the tank to the "drying floors," over which it is spread in a layer about 6 inches thick; each floor is 40 feet by 30 feet; it consists of an outer skin of boiler plates, resting on a series of brick ovens and flues. The object of this arrangement is to render the plates sufficiently hot to effect the rapid desiccation of the water from the superincumbent layer, a process generally accomplished in about twelve hours. The materials having thus been thoroughly dried, are ready for conveyance to the kilns. The "charge" consists of alternate layers of coke and raw materials, the burning generally occupying thirty-six hours. When the contents of the kiln becomes sufficiently cool, the "clinkers," or cement stones—for the mixture has now assumed that form—are drawn and removed to a floor where the larger pieces are broken, and the whole of the burnt materials are then conveyed to the hoppers of the grinding mills, where, passing under rapidly revolving horizontal burr-stones, they are ground into an almost impalpable powder. The cement issues from the mill at a temperature of about 160°, and the now manufactured material is wheeled away, and placed in a layer from 2 feet to 3 feet thick over the floor of a cool shed; it is subsequently packed in casks or sacks for conveyance from the works. The essential conditions for the manufacture of good Portland cement are: 1. The chalk and clay should be thoroughly mixed in the washmills, and the fluid materials delivered by "launders" over the *entire* area of the settling tanks. 2. The contents of the kilns ought to be burnt equally throughout. 3.

The burnt materials should be ground very fine. 4. After coming from the mill the cement should be spread over the floor of a shed, and allowed to remain there for *at least* a fortnight previously to being packed into casks or sacks.

The strength of Portland cement increases as its specific gravity increases; the tensile tests are usually made with briquettes, the standard size for the neck being 1½in. by 1½in.; and it must be understood that all experiments referred to have reference to the weight necessary to sever 2¼ square inches of neat cement.

It appears from Mr. Grant's valuable paper, read before the Institution of Civil Engineers in December, 1865, that Portland cement gains from 20 to 30 per cent. in strength by setting under water; it is usual, therefore, to place the best briquettes in water, after gaging, and allow them to remain there until they are to be tested. The following table has been compiled from a recent series of experiments; it shows the average tensile strength of Portland cement as compared with the natural cements; the test blocks were of standard size of 2¼ square inches, and placed in water, as before described:

	Weight per bushel.	Breaking weight two days old.	Breaking weight four days old.	Breaking weight seven days old.
	lbs.	lbs.	lbs.	lbs.
Portland Cement,............	119	598	914	1,024
Roman Cement,.............	76	200	240	280
Medina Cement, ...	69	280	313	313
Cement de Zumaya, (Spanish,)	84	306	..	409

The *Builders' Trade Circular* vouches for the accuracy of these figures.

Mr. Grant's tables show conclusively that the strength of gaged Portland cement increases with age; from his experiments, it appears that the breaking weight of rest blocks, one week old, one year old, and two years old, are as 1, 1.5, and 1.62. The ultimate maximum tensile strength has not as yet been ascertained; experiments are, however, being conducted periodically with a view to determine this important point. Mr. Grant gives the average tensile strength of cement weighing 119 pounds to the bushel as 777 pounds, whereas we give it as 1,024 pounds; the excess of the breaking weight, as recorded by us, may probably be accounted for by improved manufacture since Mr. Grant's experiments were made.

Portland cement now forms an important item in the list of our manufactures; but even now its valuable properties are not as fully appreciated as they deserve to be.

Good Portland cement should present a fine and homogeneous powder; it should set firmly and quickly, when used in works exposed to the surf, filling up joints in water works, etc., otherwise too rapid setting is not desirable. It should neither contract nor expand; it ought to assume a uniform, bright, gray-stone color, free from brown spots; it should possess great cementing properties, adhere strongly to the stone, and bear a high addition of sand. Finally, it ought to be free from adulterations, while the ton should have the generally adopted weight of 200 kilogrammes. It is to be recommended, under all circumstances, and

even if the cement has been procured from well-known manufacturers, to weigh it on delivery, and to keep an accurate account of it. It is very often the case that the weight is considerably below 200 kilogrammes, due either to the frequent use of the same barrel, which almost inevitably gets smaller, or to bad packing, which produces incompactness; or to unpacking it in smaller barrels, which is often done by second or third hand dealers.

A difference of ten or twenty kilogrammes per ton, which often occurs away from the centres of trade, ought certainly to be taken into consideration, if occurring in larger quantities.

In order to examine cements for their fineness and uniformity of mixture, it is only necessary to pass samples of different barrels through sieves of twenty meshes per centimetre.

There should, properly speaking, remain nothing on the sieve, and under all circumstances, preference must be given to the cement which most nearly fulfills these conditions; for the finer and more uniformly the cement is divided, the more promptly and simultaneously will the chemical reactions take place, the more perfect its combining and cementing properties, and the less fear is to be entertained about a durability of the mass after it has once properly set. The most common adulterations are inferior or spoiled cement, slags, ashes, clay and sand. They are most easily discovered by constant shaking of a sample with an abundant amount of water, after which it is allowed to settle in a high, narrow vessel. The cement to be examined is to be put in the glass filled two-thirds full of water, after which it must be shaken at once, or the cement

will cake together and stick to the vessel. Ashes and clay deposit on top, on account of their smaller specific gravity, and the water in this case generally looks turbid. The upper portion of the sediment generally fails then to harden at all, but exhibits a distinctly different color from the rest of the mass. A close examination of it will then usually disclose the nature of the adulteration.

An addition of ashes may be recognised by treating the upper layer with muriatic acid, upon which an abundant development of carbonic acid will take place, while a plastic residue indicates an adulteration with clay.

Sand will be found divided throughout the mass, but especially in the lower portions. It is discovered in treating the cement, by moderately strong boiling muriatic acid, which dissolves the cement, but leaves the sand behind.

Most dangerous, however, because not recognisable at all, is basic slag, or spoiled cement, which necessarily injures the binding quality and strength. An adulteration of this kind is not very injurious when the cement is not much exposed to the action of water, if a slag is employed that is not too basic, and that sets with lime, as is the case with many blast-furnace slags. In such cases it is acted upon by the liberated lime, and thus it becomes a cement itself, while superbasic and very acid slags, that are not decomposable by acids, behave as inert masses, taking simply the part of sand.

When made into a paste, with sufficient water to produce a mortar which slides smoothly from the

trowel, pure cement should not set in less than twenty or thirty minutes.

Yet the view that the most quickly-setting cement is the best, is found to be quite generally disseminated. We read, for instance, in a book on this subject of recent date: "Excellent cements, such as the Portland cement, Roman cement, and others, if immersed in water, harden in a few minutes, while inferior cements only attain after a few hours such a degree of hardness that they will not take an impression by the fingers."

This view is not quite correct, for it can be proven that rapidly-hardening cements will, under otherwise equal circumstances, never attain such a degree of solidity and strength as slowly-setting ones. They will, therefore, not bear the same amount of sand.

Rapidly-setting cements ought, therefore, to be avoided when possible, and only used in filling up cracks in water works, or for similar purposes; firstly, because they fail to attain the same degree of solidity and power of resistance as the slowly-setting ones; secondly, because they can only be worked with difficulty in small quantities, and only giving the best result of which they are capable, when the mason is exceedingly prompt and skillful; thirdly, because they accomplish much less than they really should by being worked in a careless manner, besides causing considerable delay.

For, if the hardening process has once begun in the mortar-box, the most assiduous working up of the solidifying mass will not (especially if more water is added) entirely remedy the evil.

By employing slowly-binding cements, these drawbacks are in a great measure avoided. Portland ce-

ment, which, if mixed with the necessary amount of water, say from thirty to forty per cent. in weight, and if not setting in less than twenty minutes, will scarcely increase in temperature; quickly-hardening cement, however, will get hot in consequence of the rapid chemical action which takes place. Still, there exist also limits in regard to slow-setting. If it sets too slowly, it remains resistless, and is pressed out of the joints, for which reason the continuation of the work will be prevented until the mass is sufficiently hardened.

If once set under water, the cement should continually get harder without changing its volume, cracking, or perhaps even falling to pieces. The cement should completely fill the mould in which it has been prepared as thick paste; it should not suffer any contraction by the evaporation of water added in surplus. On the other hand, there should be no increase of volume by swelling.

The tests to be made follow from these considerations:

Small preserve-glasses are filled with cement and the necessary quantity of water; another portion is spread over a glass plate, or a previously well-moistened brick, so as to form a cake of about five centimetres in diameter, or a larger surface is covered with a layer of one centimetre. From the rest some balls are formed before it has become solid, or a new portion of the powder is taken, and so much water added that balls may be formed.

A sewer constructed of concrete, consisting of one-seventh cement to six-sevenths of sand, and lined inside with cement, was regarded by Mr. Grant as the cheap-

est form of sewer combining strength with soundness. Tables were also given of the strength of 589,271 bushels of Portland cement, used during the last five years on various works south of the river Thames, showing an average tensile strain at the end of a week of 806.63 pounds, equal to 358.5 pounds per square inch, being an improvement on that reported five years ago of 89 pounds per square inch. At the end of thirty days, 37,200 bushels of the same cement, as ascertained by 1,180 tests, had an average strength of 455 pounds per square inch. Further experience had confirmed the earlier conclusions that the strength of Portland cement increased with its specific gravity, its more perfect pulverization, and its thorough admixture with the minimum quantity of water in forming mortar. Heavy cement, weighing 123 pounds per bushel, took about two years to attain its maximum strength when used pure; but by the admixture of sand or gravel, cement, mortar or concrete was reduced in strength, and set less rapidly than pure cement. Roman cement, though from its quick setting properly very valuable for many purposes, deteriorated after exposure to air before use about twice as much as Portland cement, if measured by strength. In making cement concrete, it would, from this, seem desirable to spend no more time than was absolutely necessary to effect a thorough admixture of the cement with the sand and gravel.

Under the name of liquid stone, is the application of the alkaline silicates in the following manner:

"The first idea that suggests itself of the use of such a liquid, is the preparation of *artificial stones for ornamental and building purposes.* Should it be possible to produce this petrifying liquid cheap enough, building stones in all their variety could be made and cemented together with the same petrifying solution. The cost of cast flint marble statuary, tombstones, baths, tables, mantel-pieces and ornaments of all kinds, would be, of course, much less than if laboriously cut from the stone, and they come quickly into universal use. In a similar way, as photography now diffuses the master-pieces of the art of painting among all classes of society, and cultivates their taste, the art of *casting flint-marble* would multiply and diffuse the master-pieces of sculpture, and adorn our public buildings, gardens and parks. Bas-reliefs, cameos, cornices, columns, pillars, etc., might be produced at comparatively cheap prices. Should the liquid be of a kind to permit its application to outside or inside walls, like plaster, then we could cover our brick and stone houses with white or colored flint-marble fronts, and our churches, halls, theatres, parlors and rooms with *glass-like walls* and ceilings, colored *ad libitum* with elegant frescoes as durable as the still fresh paintings at Herculaneum and Pompeii; while the floors could be inlaid with beautifully colored stones in mosaic style.

"Another important application for such a liquid would be the one to *render wood non-inflammable, rot and water-proof.* By making wood non-inflammable, we should greatly diminish the danger to which most of our old and new buildings are now exposed. This could easily be effected, and with not much cost, by impregnating the wood with a properly prepared solu-

tion of flint; for, if once the pores of the wood, which by their capillary action cause the communication of the fire to the whole structure, be stopped up by the incombustible and non-conducting silica, the wood becomes non-inflammable, and at the same time proof against water and decay. Not less important would be the partial silicification of rail-road sleepers and cross ties, house, ship and bridge timber; they would be stronger and last longer. Telegraph poles would, when properly treated, become more durable, and be, in addition, better non-conductors of electricity. What a new field would such a petrifying fluid open to the manufacture of incombustible paints and varnishes? It might also be mixed with paper pulp, or cheap vegetable or animal fibre, and serve for the manufacture of a variety of useful articles, such as staircases, boxes, trunks, soles for boots and shoes, patterns, moulds, handles, parts of machinery, photographic instruments, piano keys; and, further, it might be used as a coating for preventing the oxydation of iron or other metals. We must not overlook another important application in the use of the liquid flint—the one for the preservation of old monuments and stone buildings. It might, perhaps, also serve as a medium for the preservation of meat, fruit, vegetables, eggs, etc. The linings of barrels, for oils and other liquids, the coating of tanks, tubs, sulphuric acid chambers, etc., are other useful applications of this liquid.

"Metallurgy could be very materially benefited by a process whereby quartz could cheaply and speedily be dissolved in water; for we could then take the gold quartz of Nova Scotia, New-Hampshire or Cana-

da, and dissolve the quartz and obtain all the gold as a precipitate. Of course, as the liquid flint could be used for so many useful purposes, and be sold for a good price, the extraction of the gold would be very cheap, and, so to speak, cost less than nothing, as the extraction price of the gold would be more than paid for by the amount realized from the sale or use of the liquid."

Hydraulic Mortar from American Limestone.

These limestones contain mostly lime, silica, alumina, oxide of iron and magnesia, which form the proper materials for the preparation of mortars; they will withstand the action of water and moisture better in proportion, as the quantity of silica, alumina and magnesia is larger; they contain 40 per cent. carbonate of lime, 30 per cent. carbonate of magnesia, and 20 per cent. silica, the balance is alumina and oxide of iron, and they form a good mortar and a good building material; but when the magnesia is too prevalent, will deteriorate it for building purposes, it being too friable. The dolomite, which is also called bitterspar, a magnesian limestone, is a double carbonate of lime and magnesia, and abundant in the United States, is a granular limestone, and a hardness of 3.5, a spec. gr. of 3.1, and consisting of 70 per cent. lime and nearly 40 per cent. of magnesia and some oxide of iron and manganese; is unfit by itself as a building material, having a great tendency to crumble into small fragments, and forms likewise an inferior material for burning and converting it into cement, because it lacks the silica in-

dispensable for this purpose. By an addition of an alkaline silicate, either the silicate of potash or soda, and an addition of some alumina, will, after burning, produce a good hydraulic cement, particularly in such localities where no good native hydraulic limestone is found. Not alone France and Germany are particularly rich in deposits of hydraulic lime, and in the United States likewise, but these in our neighborhood may be particularly mentioned at Rondout, on the western shore of the Hudson River, 100 miles distant from New-York. The quarrying in those subterranean rocks for hydraulic cement and also common limestone is carried on in that region, along a large extent of the valley of the Rosedale River; through this valley the Hudson and Delaware Canal is constructed, which brings the coal from the Lackawanna valley at Carbondale directly to the Hudson River. This coal being a very pure anthracite, is admirably adapted for use in the limestone and cement furnaces situated at the junction of this canal with the Hudson River.

In burning hydraulic limestone, not only the carbonic acid and water of hydration are drawn off, as is the case with common limestone, but after the lime and magnesia have parted with their carbonic acid, at the high temperature of the furnace, they act on the silica and alumina, as it were, like two powerful bases, and a silicate of lime and magnesia, as also silicate of alumina and aluminate of lime, are formed. The exact chemical reaction during the burning process is, however, as yet not well understood, and undoubtedly varies in different limestones, according to their chemical constitution, which latter appears also to

vary considerably, but without affecting materially their useful properties.

In regard to the theoretical causes of the hardening process, which takes place under water, it may be remarked that this curious and interesting phenomenon, being of an entirely chemical nature, has largely drawn towards itself the attention of eminent chemists, who have attempted to explain it in accordance with well known chemical laws. All hydraulic limestones may, by the ordinary method of analysis, be decomposed into two component parts; the one consisting of the carbonates of the earth, such as lime, magnesia, etc., which, like ordinary limestones, yield a fat lime; the other, a silicate, or rather a mixture of the silicates of alumina, magnesia, lime, and sometimes potassa, as we find in the felspar, which is a silicate of alumina and potash, and a greater or less excess of free silica; the latter constituent is, therefore, simply a kind of clay. The reaction during the burning process has been already alluded to. Now, when such freshly burnt cement is mixed with water, the excess of caustic lime as well as the compound into which the silicious clay has been converted during the burning, react upon one another in such a manner, that a solid stone-like silicate is produced in the humid way, the water has a double action; dry substances, such as lime and silicate of alumina, do not act one upon another, unless the solvent power of water is brought into play so as to bring them into close contact; the water transfers continually the lime it dissolves to the silica. The absolute necessity of keeping such mortar under water, in order to have it harden, is thus explained. Another action of the water is this: it enters into a state of

hydration in the silicate of lime as soon as formed. It must also be observed, that the molecular condition of the silica is of the utmost importance in this process. Fine sand will not combine with lime, when the latter is dissolved in water that is in a form known under the name of limewater; but silica, precipitated from a soluble glass solution by means of an acid, which produces the gelatinous form of silica, will at once combine with the lime in limewater and form a silicate of lime. The silica in the hydraulic mortar is also in a state, not like fine sand, but chemically combined and dissolved in the mass, and therefore ready to combine with the lime in limewater. Next in importance to silica is the magnesia, which renders the lime hydraulic, which, according to Fuchs, has been proved that lime and magnesia well mixed will harden under water to a certain extent without the addition of silica; for we have in Germany a hydraulic lime containing only 4 per cent. When silica is found to the extent of 52 per cent., the point of saturation is reached, and such limestone is no more hydraulic. Alumina and iron may be entirely absent, although the former is always present in the best kinds of hydraulic mortars, of which that of Rondout, usually called Rosedale cement, and with the employment of which the Croton Water Works of New-York City were built, is the best on this continent.

It is confidently to be hoped, that by the proper application of alkaline, silicates will contribute much to the manufacture of an artificial hydraulic cement.

German Hydraulic Cement.

This material, artificially prepared, is in great use, and is of very peculiar composition; unquestionably it is intended to form a silicate-aluminate of lime, or, in other words, an argillaceous silicate, but the admixture, such as charcoal and iron filings, cannot be explained, but the base being obtained by the production of an alkaline silicate, bespeaks for it a useful vehicle as a cement.

It is prepared with 25 parts common clay, 60 parts lime, 10 parts magnesian limestone, 10 parts iron filings, and 10 parts of black oxide of manganese; these materials, in very fine powders, are made plastic by the liquid silicate of soda, at once applied as a cement or mortar, but it will not set at once, six hours being required for the mass to harden.

Hardness of Ancient Mortars.

Mr. Spillar communicated a paper on this subject to the British Association in 1868, of which the following are the conclusions, from the chemical examination of the ancient mortars from Burgh, Pevesney, and other Roman castles: that the lime and carbonic acid are invariably united in monatomic proportions, as in the original limestone rock; and that there is no evidence of the hydrate of lime having at any time exerted a power of corroding the surfaces of sand, flint, pebbles, or even of burned clay, with which it must have been in contact for long periods. Further, that the water originally combined with the

lime has been entirely eliminated during this process of recarbonation; and this stage passed, the amorphous carbonate of lime seems to have been gradually transformed by the joint agency of water and carbonic acid into more or less perfectly crystalized deposits or concretions, by virtue of which its binding properties must have been very considerably augmented. Messrs. Abel and Bloxam assign, as one of the causes of the hardening of mortars, the formation and subsequent crystalization of the carbonate of lime.

Stinde proposes the silicate as a very useful cement, by mixing equal parts of oxide of manganese and oxide of zinc, and making them into a thinish paste with the silicate of soda, which paste, quickly applied, sets very rapidly; and by mixing the hydraulic lime to this composition, it is a cement which will resist permanently also the action of water and heat.

"Cement and Mortar of the Ancients.

"We all know how enthusiastic some are in their praises of those ancient structures which have resisted for ages the ravages of time. They imagine that they are at liberty to draw conclusions which are not the most favorable to the architecture of the present time. Although they may be in a measure correct, it cannot be denied that such critics are too partial in their admiration for things ancient as opposed to things modern. We frequently hear the remark that some of the Roman mortars have endured for eighteen centuries the vicissitudes of time, while many buildings of now-a-days present, in a very brief period, the sign of quick decay; but they forget that these ancient

buildings constitute an exceedingly small fraction of the enormous number of those erected during many centuries in Egypt, Greece, Rome and her provinces. They do not consider that thousands of temples, palaces, and private dwellings have been entirely destroyed. And what answer can they assign to the fact that the very complaints they indulge in were even more frequent then than now? Pliny asserts that the reason of the falling in of many buildings in Rome was to be attributed to the fact of the bad quality of the mortar.

"Still more important than this argument is that of Vitruvius, the architect of Augustus. He has left a work on Roman architecture in which we find nothing that entitles us to place the architects of antiquity above those of the present time. Again, it has not been taken into account that a great part of the extraordinary strength of antique architecture is more the effect of time than the mechanical skill of the builder, or the virtues of his cements, as we propose to show hereafter. Pliny and Vitruvius both explain, to the best of their knowledge, what kind of materials the builders selected for their cements, and how they were prepared. The process was identical with the modern *modus operandi.* It is true that the old Romans were particularly careful in the selection of materials for their mortar, as well as in its preparation. They were aware that they must calcine the limestone, and mix it with sand, in order to apply it; but did not possess any correct idea of the change which limestone undergoes in the process of calcination, nor of that which is the cause of the cohesive quality of mortar.

"Many centuries elapsed before these facts were understood and explained. Black, in 1757, started the explanatory theory by the discovery of carbonic acid. A few years previous to this, Marggraf, the discoverer of sugar in beets, found the elements of gypsum, which was already employed by the Romans; and, in 1768, Lavoisier demonstrated the causes of the hardening of burnt gypsum when it is mixed with water.

"The ancients, therefore, put their practical knowledge to the best possible account. As they were deficient in chemical knowledge, they were guided only by what observation taught them. Their chief care was centred in the exterior. In the selection of limestone, the color decided. The white ones were considered best, and the colored ones were seldom used. Those taken from the interior of the earth were preferred to the stones which were met with upon the shores of rivers. A law provided that the lime must have been slaked three years before it could be used. The same also prescribed the quantity of sand which must be mixed with the lime, mentioning also that crushed cherts imparted a greater strength to the mortar. Its preparation was, as it were, a state affair, the censors watching carefully over it. In spite of all this, it often happened, as Pliny states, that they did not attain the object in view.

"But in the advance of chemical science, the fact has been established that a mortar can be prepared that, in the course of one or two years, will be as strong and durable as Roman mortar after the lapse of two thousand years. The builders of the ancients were not farther advanced than those of the middle ages.

The walls of the Bastile, for instance, were so strong that they had to be blasted away. This had likewise to be done in the removal of the remnants of a bridge at Agen, built about the year 1200; and the mortar of a bridge erected at Cahours in 1400 was even found to be considerably stronger than that of the antique theatre of the same city.

"The Romans were also acquainted with hydraulic cement. The merit of this knowledge is, however, considerably lessened, when we consider that the same is found in the volcanic districts of Southern Italy. A mere accidental observation, the same being, perhaps, mixed with sand instead of lime, may have led to its application. Says Vitruvius: 'There exists a kind of dust which produces strange things; it is found near Baja and the Vesuvius. When mixed with lime, it forms a mortar which not only imparts great strength to buildings, but also to water-works.'

"The natural cement in question is a volcanic pumice-stone, like breccia, which is still found in the environs of Naples. At a less remote period of time, when the Romans invaded the valleys of the Lower Rhine, they easily recognised the volcanic nature of the Brohl Valley. Here, as well as amid the surroundings of the beautiful Laacher Lake, which lies like a jewel set in the midst of the long-extinct Rhenish volcanoes, they discovered another natural cement—the trass—in such considerable quantities, that the quarries which were opened at that time are still in existence. The use of hydraulic cement in ancient times could, therefore, have been only a limited one, as it was found only at the two places mentioned. Its artificial preparation was not under-

stood. The solution of this problem was reserved for the investigating minds of the present progressive century."

"Hydraulic Cement.

"This material is justly esteemed far superior to metal of any description for the lining of cisterns, the water-proofing of cellar-bottoms, and similar purposes. A few directions for its preparation and use may not be out of place. To make water-proof work, it must be borne in mind that *common lime* must not be used at all; for on common lime water or moisture has an effect just the opposite to that which it has on the *water lime*, rendering it soft and quite friable when dried; whilst on the water lime the well-known effect is to make it perfectly hard. No mixture of these two varieties of lime can, therefore, be made under water. But, although they do not act well together even under ground, they serve well in dry places, such as buildings whose walls are of extra thickness; and if proper care be taken, they will conjointly form a very compact and powerful cement. The fact that water lime shrinks when wet, while common lime, in the same state, swells, at once points out the manner of treatment to be pursued in uniting the two thoroughly. Thus, it is necessary to ascertain the per centage of shrinking of the one and increase in the other, as nearly as possible, before the proportion of one to the other can be determined, with a view to their intimate combination. Such experiments are the more necessary when we consider the great difference which exists in the quality of both kinds of lime in various lo-

calities. The simplest and most effectual mode of testing water lime is to put several portions of different makes into small bags of flannel, and throw them into a basin of water. After three minutes' immersion, take them all out at once, and squeeze each in the hand. Then take off each bag, and that which is best is *firmest*, and when thrown naked into the water again, loses least of its outer coat. If none of them will bear uncovering at three minutes, try four, five minutes, but this latter should be the longest test. The test for common lime is, on the contrary, the bursting open and evolving of caloric in a greater or less degree ; and the consequent action of the water will show, by its bubbles, the power of the lime.

"It is the per centage of clay contained in any specimen of lime that determines the solidifying property of the cement made from it. The best hydraulic lime contains silex, lime and magnesia, or alumina. Its solidification is attributable to the formation of silicate of alumina and lime, or of magnesia and lime, which combines with water, and produces a hydrate excessively hard and insoluble in water. The hardening of hydraulic lime may, then, be compared to that of calcined plaster, which also combines with water to form a solid hydrate ; which calcined plaster, from the large quantities of it manufactured near that city, is commonly known as *Plaster of Paris*. A limestone containing thirty per cent. of clay makes a quick-setting cement ; and we have in the United States the Rosedale and the Belleville cements, having forty and fifty per cent. They become exceedingly hard when plunged in water for from two to three

minutes. Both these cements, especially the former, have been used extensively by our engineers.

"Inferiority in the quality of hydraulic lime may be produced by the want of proper care during its manufacture, the stone being calcined at too high a temperature; the double silicate in such case becoming a sort of *frit*, which does not hydrate in contact with water.

"As hydraulic lime is expensive according to the distance of its transportation, we will here give the method of making an artificial hydraulic lime, according to the highly successful experiments of M. Vicat, a celebrated French engineer, and the author of a much esteemed work on hydraulic cement, who first pointed out the method to be adopted in its formation. It is prepared by stirring into water a mixture of one part of clay and four parts of chalk; these materials should be mixed by a vertical wheel turning in a circular trough, and made to flow out into a large receiver. A deposit soon takes place, which is formed into small bricks, which, after being dried in the air, are moderately calcined. Hydraulic lime thus prepared enlarges about two-thirds in volume when placed in water. Like the natural hydraulic lime, it can be completely dissolved by acids. This invention of artificial hydraulic lime has rendered Vicat deservedly famous, as it has been in use for many years in the public works throughout France, and was even employed in the hydraulic masonry of the St. Martin canal. That it can be made in this country there is no doubt, as the argillaceous or potter's clay required is to be found almost everywhere.

The new cement which M. Sorel proposed to the

French Academy consists in the application of a basic hydrated oxychloride of magnesium, may unquestionably be improved by means of a silicated hydraulic lime and the bittern of the salines, which is a chloride of magnesium in a concentrated condition.

Lime, sand and clay, when mixed with water, form the so-called composition of a hydraulic cement; they are fit to unite solid surfaces by hardening after a few days' application, under water, by forming a combination with the constituents of either surface. Walls and piers have been built for over one hundred years, and after being exposed under water have become harder and harder. This cement is also called Roman cement, because the natural materials are found in abundance in the Roman district where the tufas, puzzuolanas and trass, all products of volcanic districts, like the Pontine Marshes of Rome, and near Naples, are abundant, and consist of those elementary substances. In the voltaic formations of the triassic period the marls or green sand, the curious nodular and lenticular concretions, the Septarias and ludus Helmontii, of turtle shape, all found in argillaceous strata of the sedimentary rocks which are alternating with limestone beds, and all found in abundance on the English and French coasts and the United States, all of them form a silicious clay intermixed with lime, and are, therefore, the proper material for a hydraulic lime or cement.

Injection of Silicates.

While engaged in impregnating the soluble silicates into the porous stones, and carrying this operation into all organic and inorganic matter, the convincing proof was manifested that the hardening of these bodies are only owing to the decomposition of the silicates, effected by the slow action of the atmospheric carbonic acid and the gradual condensation of silica. This phenomena led to the observations that the natural silicates and aluminates, as well as other mineral species, were similarly formed in the moist way.

This remarkable reaction of hardening porous bodies by silica proves, by geological observations, highly probable that not alone all the enveloped and crystalized minerals found in limestone formations, but also an endless variety of silicated and aluminated substances found in nature, owe their existence to analogous causes; that the flints, agates and petrified wood cannot have any other origin, but that they are formed by the slow decomposition of a silicated alkali from the carbonic acid, either atmospheric or generated during the process.

This fact is of the highest interest in the chemico-physical investigations, and is the key to the investigations of the formation of the natural silicates, even under many various circumstances, of the condensation of silica by other bodies than the carbonic acid; many experiments undertaken have proved the gradual decomposition as already stated, and in a great variety, of the formation of such as opal, quartz, and others depending, likewise, of the state of concentra-

tion of the original decomposed materials. The iridescence of the opal, which disappears if exposed long to dry atmosphere, but revives if moistened in water or sweet oil, gives a beautiful example. Many important facts have come to light by the investigations made on hydraulic limes and artificial stones, which prove that a considerable quantity of potash is contained in the natural hydraulic and other cements; the origin of which is attributed to the decomposition of the alkaline silicates by the lime, and this may be proved by the formation of saltpetre or nitrate of potash in the efflorescences of walls and earths in caves, called an eremacausis of substances which contain nitrogen, and form, therefore, ammonia, and in contact with porous substances undergo an oxydation and conversion into nitric acid, and at once is combined with the alkalies contained in the native lime occurring in the older formations, and was separated, under certain circumstances, from the alkaline silicates found in those limestones—nitrate of potash the result. In general terms, nitre, or nitrate of potash, which is found in crusts on the surface of the earth, on walls and rocks, and in caves, is found in those localities in certain soils of Spain, Egypt, Persia and East Indies, especially in hot weather succeeding rains; it is also manufactured from soils where other nitrates (nitrate of lime or nitrate of soda) form in a similar manner, and beds called nitraries are arranged for this purpose in many countries. Refuse animal matter also, putrified in calcareous soils, gives rise to nitrate of lime, as we find it so frequently n cow and horse stables, and is then converted into nitrate of potash; old plaster walls, when lixiviated, afford about 5 per cent. of nitre. It is known that

nitre requires for its formation dry air and long periods without rain; the potash comes mainly from the debris of felspathic and lime rocks in the soil, or in the cements, if they have been used for building walls, and the oxydation of the nitrogen of the air is promoted by organic matters, hence the nitre is generally associated with azotized decomposed organic substances. A nitre crust from the vicinity of Constantine, Algeria, afforded Boussingault 85 per cent. nitrate of potash, with some nitrate of lime, soda and magnesia. In the Mammoth Cave of Kentucky, where the nitre is found scattered through the loose earth in great abundance, and was utilized during the war of 1812, also in the Mississippi Valley, in Missouri, many caves have yielded the nitre which was of great use to the secessionists of the late war, when Tennessee, along the limestone slopes and in the gorges of the Cumberland table land, produced a large amount of saltpetre.

The nitrate of soda, formed in a similar manner like that of nitrate of potash, but more particularly found in the dry pampas of Chili, where it is found at a height of 3,300 feet above the sea, contains beds of several feet in thickness, along with gypsum, common salt, glauber salt, and the remains of recent shells, indicating the former presence of the sea.

Kuhlmann has proved by his investigations that the larger number of limestones from various geological periods contain both potash and soda, deriving their existence from various plants growing in a calcareous soil, and has also shown the development of the efflorescence of the carbonates of potash, chlorides of potassium and sodium, which make their appear-

ance on the surface of walls from their construction, to which he was led by the fact that the alkaline salts in general are obtained in larger quantities from hydraulic limes than from the lixiviation of air limes; that the hydraulic limes contain mostly more alkali; that it exerts much influence upon the quality of lime; and it has been ascertained by Vicat that the occurrence of the potash and soda is neither accidental nor less influential upon the proportion of the hydraulic limes. It is presumed that the silicated limestone, and any fat lime mixed with clay by the influence of potash or soda, are, during the burning, converted into double compounds, analogous to the natural silicates, which are known under the name of zeolites, such as mesotype, stilbite, apophylite, etc., which all form hydrates, and lose their water of crystalization by burning, and absorb it again on moistening; one of the species of that class of mineral, such as the laumonite, which, when exposed for some time to the atmosphere, effloresces and crumbles to pieces to the chagrin of the mineral collectors, but it is sufficient to confirm the remark just made regarding their constitution and similarity of the artificial silicates of lime and alumina. It is apparent that, in the hardening of hydraulic lime, a process takes place analogous to that of gypsum when hardening, and forming a hydrate. It may, however, be possible that the hydraulic limes be still formed without the presence of potash or soda, and that the silicium or aluminum in contact with lime fills the same office in possessing the property of binding the water, and to convert them in certain conditions to a hydrate. Respecting the cement which is formed by the moist

way, it is a fact that when chalk is brought in contact with solutions of alkaline silicates, an exchange of the acids of both salts takes place, one part of the chalk is converted into silicate of lime and the corresponding quantity of potash in carbonate of potash; this explains the true artificial stone, which has become, on exposure to the atmosphere, so hard, that, if the mixture contains a sufficient quantity of a silicate, possesses the property to adhere firmly to such bodies where it has been applied, the materials so formed with the silicate of potash or soda are analogous to cements without burning, and may be used for restoring monuments, etc. In the silification of artificial stones, the affinity of lime to the silica contained in the soluble glass is manifest, and shows the effect of the alkaline silicates on limestones; and how the influence of the atmosphere in the hardening of silicates or artificial limes is brought to bear through the atmospheric carbonic acid by the separation of one part of silica in the silicates, and how the other parts of the silicate, when in close contact with a sufficient quantity of carbonate of lime, a lime silicate is formed.

This acquired knowledge has produced numerous applications in industry; it has proved that, by artificial impregnation of mineral substances into the interior of porous substances, organic as well as inorganic matters are preserved, or silicified. The silicification of fine sandstone is easily effected by the mixture of 1 part of liquid silica, and 2 parts of fine sand, with the addition of a small quantity of chalk and white clay, all of which are wrought into a paste, and then formed into desired objects and exposed to the atmosphere for some time, and the finishing pro-

cess continued by means of hydraulic pressure and heating in hot chambers, the particulars of which have been indicated in a former chapter. It has been ascertained that always, if any salt insoluble in water is brought in contact with the solution of a salt which forms with the acid of the base of the insoluble salt a less soluble substance, an exchange takes place, which, although but partial sometimes, produces the formation of double salts. This discovery led to a direct application that white lead, chromate of lead, chromate of lime, and the majority of the carbonated metallic salts, are suitable for silicification.

THE SILICATE PAINTING ON STONE,

STEREO-CHROMIC.

THE use of the brush in the application of colors has so far been but partially accomplished. The substitution of the potash or soda silicate for the fixed and volatile oils with mineral colors, has at first been attempted by trituration of white lead with the liquid silicate. It has been found that a transformation of the white lead takes place the moment they come in contact together, which is so rapid that no time is allowed to transfer the paint into the brush. In order to make this paint more suitable, and to prevent a kind of decomposition, it was found advisable to add a large portion of the sulphate of baryta, artificially prepared, as this paint operates but slowly on the silicate solution.

It appears that this baryta may be used with more advantage by itself, as it unites perfectly with the silica, and appears to form a chemical compound, but a disadvantage presents itself in forming but a half transparent color, which does not cover well, and the addition of oxide of zinc is therefore recommended, which agrees well with the paint in connection with baryta and silica; this application has produced very satisfactory results, forming a cheap white paint, which can be easily transferred with a brush.

Many mineral colors, mixed with white bases, pro-

duce such difficulties on account of their drying too quick, others too slowly, according to the behavior of the bases to the soluble glass. Many combinations retain the alkali obstinately, and it was attended with many difficulties to apply the colors with the liquid silica; yellow ochre, blue and green ultramarine, sulphuret of cadmium, peroxide of manganese, the oxide of chrome, have proved to unite well with the silica.

The painting on stone is much easier when silica has been used on the stone than on that where it was not applied, for the reason that the absorbing quality of the silica, serving a binding material, withdraws it from the color, and it is therefore very advisable to apply several times the liquid, and exposing to the atmosphere before applying the paint. A single silicification of the wall is indispensable on the painted coloring, which is done by preparing, as usual, with the liquid silica, as other paints are treated. The soda silicate, used for painting on walls, is easily effected by the use of the syringe. The painting on walls is attended with some difficulty likewise, for while that on stone remains unaltered, the wood is apt to shrink, or to crack, and many woods will not easily take the paint, and even change their physical appearance, becoming darker; oak wood assumes the appearance of an old wood, and only the white and hard woods, such as the ash and maple woods, will take up the silicate painting. Another difficulty takes place in painting on wood, that it peels off, if applied too thickly. A weak solution of 1 part silica, of 28° B. to 5 parts water, either alone or combined with other bodies, is recommended.

The new art of painting—Stereo-chromic—derives

its names from two Greek words, στερεοσ, fast, or permanent, and from χρωμα, the color, and has been introduced as a substitute for fresco painting, and bids fair to be very extensively applied, and more than the encaustic painting, from the fact that the works executed by this art have given great satisfaction; the inner halls of the new museum at Berlin have been painted by Kaulbach with panels 21 feet high and 24¾ feet broad, and are said to equal the oil paintings in freshness and vigor, and with that particular advantage, that the paintings may be viewed or examined from a certain stand to do so, and that it may be applied on many grounds without the rough mortar being first used. An experiment was made to expose a painting for one year to the atmospheric air, to the sun, fog, snow and rains, and retaining during the whole time its freshness. An important circumstance, however, is the formation of the groundwork, for any neglect in that of the lower and upper ground materially affects the beauty of the painting. In order to produce a uniform strong firmness, it is necessary to supply the soluble glass uniformly, so that it may be absorbed perfectly and uniformly.

The walls must be well cleansed, in the first instance, when the mortar is laid on, and then a weak solution of the liquid glass is passed over it and left to dry. Clean washed sand or limey sand is then mixed with a very small quantity of burnt lime, and made into a paste and laid on the wall. The surface is made even by an instrument, and the upper layer removed which was formed on coming in contact with the air; but the mass must be always kept moist during the whole operation. This rough mortar will

soon become dry, and may be rubbed off with the fingers, but it must not be left too long exposed to the air, for fear of its attracting the carbonic acid, whereby the lime would be too much carbonized.

By the application of a solution of carbonate of ammonia a considerable hard consistency is produced, when the liquid may now be applied several times with a brush, but always at intervals, and enough to penetrate into the mortar, and the liquid glass ought to be that made from soda, and quite clear. In all cases the liquid must be laid on by means of a brush, in order to produce a uniform impregnation of the same. When this groundwork, called the underground, is faithfully and carefully prepared, the upper groundwork which is to receive the painting may be commenced with; it does not differ much from the first operation.

The sand to be used must be of fine grain, and well washed, as also the quartz, etc., (the lime sand,) which is obtained from marble or dolomite, finely powdered, are to be used to the thickness of one line quite evenly, in order to obtain the necessary roughness on the surface indispensable to the process of painting. It may, perhaps, be necessary to use other substances before the application of the fine sand, in order to destroy any lime crust which might have been formed in the preparation of underground, and diluted phosphoric acid is now recommended to be applied with a sponge or brush on its surface, for it forms then a phosphate of lime with the soluble glass, which binds well and does not injure the mortar. The ground so prepared, and well dried, is now impregnated with the liquid glass, the same as the first, and diluted also

with equal quantities of water, which is done twice, allowing sufficient time to dry between each impregnation.

Wood may be painted by covering it first with a chalk ground, which must be thick enough to allow a polishing with pumice; to chalk, glue or a little silicate solution may be added, as a binding material. Another difficulty occurs after the first has been overcome, in the oozing out of the carbonate of potash in damp weather, until the whole salt has been expelled, and many experiments have failed, and hydrochlorate of ammonia was first proposed in a weak solution, and an absolute insolubility of the color was thereby obtained, but chlorate of potash remained in this operation, which destroys the gloss of the colors if not at once removed by repeated washing; forced to resort to those few chemical agents, apt to fix the potash, which should enter as insoluble combinations in the color without destroying them, the perchloric and hydrofluoric acids were resorted to. It is well known, that by washing with hydrofluoric acid the density of the colors is much increased, and it was thought, therefore, safe to use it, particularly in painting on glass, but only as a very weak solution. Hydrofluoric acid possesses the most remarkable property to dissolve most oxides when in a concentrated state. The application of the weak solution of hydrofluoric acid, either for fixing the potash in painting and in silicification of limestone, was mainly calculated for such case where a silicate has been used with an excess of potash; and in hardening of soft and porous limestones by a partial conversion into a lime silicate, it was found very expedient for fixing the potash, and making

sure the insolubility to moisten, at first with a weak, and then strong solution of the hydrofluoric acid, the stones when the potash oozed out. The acid, however, penetrates the stone and produces an insoluble compound; in other words, it fixes the soluble potash, and produces an insoluble compound. Through this discovery hydrofluoric acid was found a very useful application in the fluosilicated lime.

If brought in contact with lime, hydrofluoric acid is capable of dissolving it considerably without producing an immediate precipitate of calcium, or a separation of the silica; but at a certain state of saturation any addition of lime decomposes entirely the hydrofluoric acid, and so much that not a trace of these bodies can be discovered in the fluid. The same results are obtained by the carbonate of lime, instead of the caustic lime, and that silicium and fluor are produced in the limestone, which hardens but slowly, and it is therefore simply a fluorsilicon that produces the hardening of the lime. The effect of the hydrofluoric acid on gypsum is also produced in both mixing, the surface of the gypsum is considerably hardened. If, however, the acid is used in excess, the gypsum is covered with raised pustules, which owe their existence to the formation of bisulphate of lime, because sulphuric acid does not act as well as the carbonic acid in the treatment of limestone; a fluorcalcium, mixed with soluble glass, may be used as a paint, or paste, or a cement, or any coating of other substances, and becomes so hard and weatherproof that neither soda nor potash will detach from the combination, and will remain dry.

Painting on Metals, Glass and Porcelain.

Silica painting adheres strongly on metals, provided care is taken to keep the substances some time from the contact with water. The most durable paint is produced on zinc, also on porcelain and glass; the colors assume a semi-transparency if painted on glass, and no doubt afford much inducement for its use. The sulphate of baryta, artificially prepared, combined with silicate, applied to glass, makes a milky white appearance, and is very beautiful, as it incorporates very intimately with the silica, so that after the lapse of a few days the paint cannot be removed even with warm water. If this glass is exposed to high heat, (6° Wedgewood,) a fine white enamel is formed on the surface, which will compare well with the oxide of tin, and is much cheaper. Ultramarine, oxide of chrome, if converted into enamels, form a prolific source for the new art of painting. It is not quite necessary that a chemical combination should be produced in all these colors, if they only adhere strongly and produce the silicated cement, which has become hard by its fine division and easy admission of air.

Emery, bloodstone, and peroxide of manganese, if finely powdered and prepared with a concentrated solution of soluble glass, produce cements of extraordinary hardness, resisting the effect of heat completely, and become perfectly insoluble in water.

For the production of an indestructible ink, soluble glass has been used and obtained by mixing finely burnt lampblack with the liquid soluble glass. *Braconnot's ink* is prepared by decomposing leather in

caustic potash, and adding to the black mass the liquid soluble glass. *A decoction of cochineal* mixed with the liquid soluble glass, produces a red ink, resisting completely the action of chlorine and all other acids.

Stereo-chromic for Easel Painting.

The basis for this class of painting may be made from plates of burnt, porous clay; it is first impregnated sufficiently with liquid soda glass. These plates may be three-fourths of an inch thick; after one or two applications they become as hard as any stone ware; they are very suitable for painting ground. The lithographic stone makes a good base for easel painting; a thin coating of liquid glass mortar will produce a good base, and it may be first moistened with phosphoric acid, which assists much to absorb the colors with the liquid glass, and to make them fast.

The colors to be used for this class of painting ought not to be chosen which decomposes the liquid glass, such as contain strong acids, nor those from organic substances. Burnt oxides are better than raw oxides, vermilion becomes brown, and at last black; cobalt blue becomes clearer by the liquid, and the yellow ochre becomes darker.

All colors ought to be properly prepared to make them fit for the silica painting, such as the great variety of oxides; many of which, not containing much oxide of iron, may be suitable, also chrome red, ultramarine, umber, baryta white, cadmium yellow, and many more, purposely made by some chemists, not containing free acid, which enter into a decomposing chemical combination.

The permanent white, or artificial sulphate of baryta, is said to be the proper material for a white paint. It is obtained from the native minerals, heavy spar or sulphate of baryta, and witherite or carbonate of baryta. The manufacture of the new paint is effected by the reduction of the native sulphate to a chloride of barium, or dissolving the native witherite in hydrochloric acid, and then adding either sulphuric acid or glaubersalt; the artificial sulphate of baryta is found in a condition of extreme fineness and purity, possessing a fine lustre, and susceptible for producing a fine white paint, which is the best substitute for white lead and zinc white, is not subject to tarnish or become brown in parlors like white lead, which is attacked by hydrosulphuric acid, and forms, when combined with the liquid glass, a slow but intimate combination, and is likewise used under the name of blancfix for card-makers, paper-stainers and paper collar manufacturers to a very large extent. It may also be considered in point of importance, if compared with that of white lead, not having a dilatory effect upon health as the latter. If mixed with the soluble glass it obviates the odious smell of linseed oil and spirits of turpentine. If it is mixed with dexterine, starch, or other binding material in connection with the liquid silicate of soda, its applications may be multiplied to any extent.

The artificial sulphate of baryta is largely manufactured on the continent of Europe; in the United States it has so far been manufactured in New-York by a few chemical establishments for card makers, but not yet for the purpose of substituting it to white lead.

SILICIFICATION OF WOOD.

A Protection against Combustion, Inflammability and Dry Rot.

Wood, and all other organic combustible substances, may, to a great extent, be preserved against that great element, the fire, by the proper application of the liquid silicates. Still it requires much skill, experience and proper management to subdue totally this wonderful element when brought to its full power. There are many instances on record to prove either a full, or at least partial success in arresting the progress of a conflagration by the impregnation or coating of combustible bodies with many substances, such as possess incombustibility, whether liquids, gases, or materials which possess the properties of generating gases, that will withdraw or suffocate the surrounding atmosphere, such as the oxygen gas, and thereby arrest the progress of the flames. Many chemical agents have been from time to time proposed to effect this object; such as salt, chloride of lime, and, latterly, carbonic acid in its gaseous and liquid form, and many metallic salts have proved but a partial success in the prevention of decay or dry rot of wood. The soluble glass is one of the first materials which have been successfully employed in arresting conflagration, and as far as 1823 this material was recommended in the construction of the Munich Theatre, where 465,000 square feet of timber

surface were treated with a coating of the liquid soluble glass, and in 1830–31 and '32 the author performed many experiments in the Brooklyn Navy Yard, partially as a protecting agent against fire, as also against decay of the woody fibre. Small square blocks of wood, after having been impregnated with the soluble glass, and sailcloth, writing paper, parchment, etc., were exposed for some time to the flame of a gas lamp. After the lapse of an hour, all these substances were found to be charred, but not consumed. It is proved that the liquid soluble glass produces a perfect adhering, permanent covering which, when properly laid on, suffers no damage from the atmosphere. For coating the wood, etc., a pure solution of the liquid glass is required, otherwise it will peel off, and it is best not to use it first in a concentrated state, as it will not be able to penetrate into the pores, whereby the atmosphere must be expelled, and even five or six applications may be made in intervals of twenty-four hours. Although this process renders good services, it may be improved by the addition of other pulverized substances, wherein the soluble glass acts as the binding material, the coating assumes a better body, is stronger and more permanent, and if exposed to the fire, a crust is formed; such, for instance, are bone dust, clay and chalk mixed together, a lead glass, etc.; common clay, one-tenth of the quantity of silicate of soda, was successfully used with the liquid glass in the Munich Theatre. If applied on linen or other organic textures, the mere coating or dipping is not sufficient, but a surface between rollers must be resorted to, in order to produce a full absorption with the pores; these stuffs may then be rolled up, but not folded.

Building timber, rail-road sleepers, and other similar materials, have been treated in the manner just described, and were protected fully against fire and dry rot.

The author proposed a combination of the liquid glass with the following substances, intended as decomposing agents by chemical affinity, and producing in the cells of the vegetable fibre the various mineral and metallic salts which are altogether insoluble in water, alkalies and acids, and he extended his experiments on the uses of lime, chalk, gypsum, copperas, etc. His process of treating ship timber, sleepers, cross-ties, roofing shingles and other wood blocks was the following:

1. The materials to be treated were put in steam boilers and exposed for four hours to a pressure of hot steam, (or 300° F.,) then withdrawn from the kettles and dried. Alkalies and acids, such as hydrochloric, have been since recommended for the purpose of abstracting color and albumen existing in the cells of the woody fibres, which, however, is accomplished by steaming.

2. In a solution of silicate of soda while hot, the materials to be treated are thrown and kept there for twenty-four hours, which will give ample time for the liquid to enter into the open cells while hot.

3. A large vat, containing either lime water, solution of copperas, or blue vitriol, white vitriol or gypsum, finely powdered and thrown into hot water, or finely powdered chalk of 1 pound to 10 gallons of water; the proportion of metallic salts is but one-quarter pound to the gallon of water. The woods are

kept in the vats for another day, and then taken out, dried and ready for use.

Coal tar, and the other products of dry distillation from tar and peat, have been recommended by Krieg as far back as 1858, under the name of Creosote-carbolic acid, which was then considered a waste product, and in its raw state having a specific gravity of 1.02 to 1.058, and yielded from 20 to 30 per cent. of the tar; it was well known to possess the property of protecting wood against decay.

This chemist combined with the impregnation of woods, etc., the soluble glass and the creosote-carbolic acid, for the reason that the latter precipitates the soluble silica as an insoluble substance while it is soluble in an alkaline lye. He proposed to expose the woods for three-quarters of an hour to a temperature of 300° F., and then drying them thoroughly.

The woods thus prepared showed an increased weight of 6 per cent., and a lacquered surface, while in the inside the pores were filled with an insoluble precipitated silica.

For effecting a still more perfect success is to fix the creosote on the woody fibre from the alkaline solution, by diluted sulphuric acid, or by a solution of copperas, (sulphate of iron,) whereby the sulphate of soda thus obtained may either be washed out, or oozed out, the creosote-carbolic acid combines stronger with the woody fibre, and the impregnated woods may be considered safely protected against fire or rot.

This process just described, deserves the serious attention of the various companies established for the last five years in the preservation of wood by carbolic

acid, tar, etc., by combining the soluble glass with their process, as we have described.

Since the introduction of rail-roads, not quite 50 years, many men have been engaged in chemical experiments upon the cross-ties and sleepers, which, after being laid down for a few years, undergo the decay or rot, and have to be renewed, which causes great expense to the companies. Kyan, Burnett, Laboucheri, and many other chemists in all countries where this evil existed, proposed remedies; the sublimate, chloride of zinc, pyrolignite of iron, all had their advantages and disadvantages; of late, borax, alum, rosin, carbolic acid have been introduced.

Wooden Roof Shingles.

One of the most valuable applications of the soluble glass may be recommended for shingles and wooden roofs of farm-houses in the country and near rail-roads, where the sparks of the locomotives have frequently caused conflagrations and destruction of property.

The operation is quite simple, and the expense but trifling; the process has already been described, but it may be still more simplified in the following manner:

After the steaming of the shingles in boilers or in tanks, where steam of 250 to 350° is led into them, they are dried and thrown into a weak solution of liquid silica, standing about 25° B., in which they are left for twenty-four hours, when they are taken out and exposed to the air. Before they are quite dry, a weak solution of chloride of calcium is thrown over them or sprinkled over them with a broom. When

quite dry they are fit for use. They will not burn nor be ignited with the sparks; if exposed to a direct fire, will not light in a surrounding fire. An intense heat of long duration may char them on the surface; they are, however, quite safe from any inflammation.

The Preservation of Wood by Immersion.

The processes for the preservation of wood may be divided into three groups, namely: processes by immersion; processes by pressure in closed vessels, (which are exclusively employed for dry wood,) and processes founded on the displacement of the sap, (which are only employed for green wood.) In the present article we shall describe the methods by immersion.

Attempts to impregnate wood by the method of immersion were the first experiments undertaken. As early as 1740, Fagol, a Frenchman, tried to impregnate wood with alum, sulphate of iron, and various other substances, in solutions of which he immersed it for several days. In 1756, Haller recommended vegetable oil for the same purpose. In 1767, Jackson indicated the use of a solution of sea salt, to which sulphate of iron and magnesia, alum, lime and potassa were to be added. In 1779, Pallas proposed to mineralize wood by dipping it first in a solution of green copperas and afterward in milk of lime. In 1830, Kyan, in England, tried to preserve wood by simply immersing it in a solution containing two per cent. of bichloride of mercury. Not long since, experiments were made in France and Germany with a large number of rail-road ties, by keeping them several

hours in a solution containing 1.5 per cent. of sulphate of copper, at a temperature of 160° Fahr. This preparation is, however, altogether insufficient for the preservation of fir or pine wood, and in general for light woods which contain a large amount of nitrogenous substances; but it seems to increase considerably the durability of oak. The wood is thus surrounded by a very thin coating, which is not liable to decay nor to the attacks of insects, and which retards the alteration of the inner parts. These are, however, not impregnated at all by the antiseptic liquid; they preserve their germs of putrefaction, which develop the easier the more the injected surface is removed, whether by friction, blows, or the driving in of nails. The decay commences then at the denuded points, and propagates itself toward the central parts.

Decay of Wood and Processes for Preserving it.

According to the experiments which were made by De Saussure, in the beginning of this century, it would seem that the decay of woody fibre was exclusively caused by the action of air and water. On exposing moist wood to the action of oxygen gas, he found that, for every volume of oxygen absorbed by the wood, one volume of carbonic acid was disengaged. It is now conceded that it is the hydrogen of the fibre which is oxydized at the expense of the oxygen of the atmosphere, while the carbonic acid is solely formed from the elements of the wood, or that the process is simply a separation of a portion of the carbon of the wood by direct oxydation; and it would seem, from the experiment mentioned, that the first and only

cause of the decay of vegetable tissue must be ascribed to the affinity of oxygen for the elements of the latter.

Such cases of slow decomposition have indeed also been distinguished by the name *eremacausis*, a term composed of two Greek words, and meaning to burn by degrees.

The above explanation, however, scarcely holds good in all cases; it is now known that, in dry air, woody fibre may be preserved without decaying for thousands of years; and, under water, in certain conditions, it appears to be equally durable. One must, therefore, look for some other cause to explain the transformation of woody fibre. Such a one presents itself in the fact that, when wood is exposed for some weeks to running water, or if it is boiled in water and afterwards dried until the original weight is restored, it is rendered thereby considerably more durable.

The cause of the transformation in question must, therefore, be sought in a substance which is removed by the dissolving action of water in the experiment mentioned. By further investigation, this substance is found to consist of the albumen of the sap, which is distributed throughout the cellular tissue. Like the animal albumen, as the white of eggs, which it closely resembles both in properties and composition, the vegetable albumen is exceedingly liable to decomposition. In this state it acts like a ferment, inducing the decay of other bodies, according to the physical law propounded in another application by Laplace and Berthollet, namely, that a molecule set in motion by any power can impart its own motion to

another molecule with which it may come in contact.

Among the bodies most prone to decomposition is the sugary element, which is first dissolved. Then the growth of fungi generally begins, and the putrefaction proceeds step by step. It may, therefore, be considered that the spontaneous decomposition of the vegetable albumen is the primary cause of the decay of wood. It is, indeed, found that those kinds of wood which contain the smallest quantity of albuminous matter and amylum are the most durable. Especially is this the case with a certain tree of the acacia tribe, the locust, and the cedar, which resist decomposition in situations where all other kinds of wood soon decay.

In order, then, to find out whether a certain kind of wood is especially fitted for building purposes, the quantity of albumen present in the fibre should be ascertained by analysis. M. Payen recommends, for this purpose, to digest the wood in a dilute solution of caustic alkali—this soda, or potassa—which has no action on the woody fibre, but only dissolves the albumen. Hence the quantity of the latter may be estimated by washing, drying and weighing the wood after the experiment has been made.

Impregnation of Wood by Pressure.

The apparatus now used in France for the saturation of timber with preservative agents is described as follows: It consists of a cast-iron cylinder, which is connected by means of a tube with a condenser. Both are placed in a vertical position. The operation is

begun by introducing the timber into the cast-iron cylinder, together with the preservative material. The latter, however, is not altogether to rise to the entire height of the stem. The receptacle of the wood is hereupon closed, and connected with the condenser. A vacuum is then produced in the latter, which is accomplished by introducing alternate steam and sprays of water into it. After this the stop-cock of the tube connecting the two cylinders is opened, when the air passes from the receptacle into the condenser. This operation is repeated until the pressure in the cylinder is less than fifteen decimetres. The same is kept up for several minutes, in order to let the air of the timber have time to escape. The connection between the receptacle and the condenser is finally closed. A pump is then set in motion, by means of which the preservative agent is made to penetrate the pores of the vegetable tissue, until the pressure stands at that of ten atmospheres. This is maintained for various lengths of time, according to the nature of the wood and the liquid, but six hours are generally sufficient. After this the air is gradually allowed to enter, while the preservative liquor is left to run away.

"The capability of wood to sustain the strain to which it must necessarily be exposed, especially when moving over it at high velocities, has been satisfactorily proved by the experience of the Great Western and other railways, where continuous longitudinal sleepers of wood have been employed, and experience has shown that the solidity of the road is much greater than when the iron rails were attached either to stone locks or transverse wooden sleepers. In

proof that wooden rails cut from beech will bear the wear and tear of trains passing over it, it is well known that beech cogs have proven to last eighteen to twenty years when working in gear with an iron wheel. The rails on the Vauxhall line were prepared by Payne's patented process for preventing dry rot and decay of timber. Scotch fir, if subjected to pressure, will crush at ten tons, while beech (the wood recommended for railways) will bear a pressure of eighty-two tons before it begins to yield.

"Experience having confirmed the capability of Scotch fir to withstand the traffic of twelve engines per day for seven years, without any visible wear, it would be difficult to say how long the rails cut from beech, sustaining eighty-two tons pressure, would last. Some of the impediments with which rail-roads have to contend are the undulations of the country, and the necessity of diverging from a right line in order to obtain the traffic of important towns. These obstacles can only be overcome by an outlay of capital, in making the required excavations and embankments, or by the oftentimes ruinous system of tunnelling; and after all, inclines of greater or less gradients are unavoidable, and prevent the line working economically. Curves on iron rail-roads are highly prejudicial, especially if the radius be small, as the wear and tear becomes proportionably increased."

Timber Rot and Seasoning.

It is generally supposed that the rotting of timber is merely induced by the action of the oxygen of the air. From analysis made of sound and decayed oak,

it has been shown that for every two equivalents of hydrogen oxydized by the air, one equivalent of carbonic acid had separated. It may therefore be inferred that the decay or rot of timber does not arise from fermentation, but is rather a chemical process. Others admit that microscopical parasites of vegetable nature play an important part in the decay of wood; but consider the presence of albuminous matter in the sap as necessary, which, according to them, must also be first in a state of decomposition before it allows the growth of those organisms. In order to throw light upon this most important subject, we propose first to tabulate a number of well observed facts. Sound timber, when immersed in water, without access of air, will withstand decay for almost an unlimited time. This is proved by the piles upon which the dwellings on the Canaries rest, which were erected in the time of the Conquest in 1402, they being just as sound now as if they had been freshly felled. Roots of trees that have been submerged in marshes are rarely found decomposed. This is stated to be the case with the utensils discovered in the lake dwellings of Switzerland, Bavaria and Lombardy, which must be at least ten thousand years old. Hartig also describes a cypress stem with over three thousand rings, representing the same number of years, which, though submerged, had only partially turned into brown coal.

With respect to the action of the atmospheric air, it may be asserted that the same, even when moist, will not produce rot if the wood has been well steamed, or exposed to the action of running water for a sufficient length of time. In England it is customary to lay the

timber destined for threshing-floors and wainscoating in fresh water for several weeks. When again dry, and not exposed to damp, such timber will endure for an incredible period of time.

This tends to demonstrate the fact, that the substance which induces decay must be foreign to the timber itself. This substance is the juice that is chiefly contained in the vascular tissue, which forms a link between the bark and the wood. The composition of this sap varies according to circumstances, as the variety of the tree, climate, season, ground, etc. The following are analyses of the sap:

In 100 Parts.	Sap of Elm Tree. Vanquelin.	Sap of Cow Tree. Solly.	Dried Sap of Bark of *Antiaris Toxicaria*. Mulder.
Albumen,	....	3.06 (*a*)	16.14
Dextrin,	....	4.37 (*b*)	12.34
Sugar,	....	....	6.31
Resin,	....	....	20.93
Galactin,	....	30.57	....
Myricin,	....	....	7.02
Antiarin,	....	....	3.56
Organic Substance, (not determined,)	0.10	....	....
Potassa with Organic Acid,	0.87	....	....
Carbonate of Lime,	0.10	....	....
Extractive Matter and Salts,	....	....	33.70
Water,	98.93	62.00 (*c*)	....
	100.00	100.00	100.00

(*a.*) Gluten and Albumen, according to Solly. (*b.*) Dextrin and Salt. (*c.*) Water and Butyric Acid.

Remarks.—The Cow Tree (*Galactodendron*) is a native of the Cordilleras of Venezuela; it furnishes, by incision, an enormous

quantity of a white, thick liquid, which has the taste and some of the qualities of a real cow's milk. The *Antiaris toxicaria* belongs to the same family as the former, namely, to the nettle-worts, and it is singular that it furnishes a most deadly poison, which has been the subject of the most harrowing stories. (Jussieu; *Elements of Botany.*)

Unfortunately we possess only one analysis of a tree indigenous to North America; however, the same tends to show that the amount of albumen, if the non-determined organic matter must be considered as such, is exceedingly small; and with respect to the other trees, these analyses prove that the albumen does not constitute the chief part among the ingredients of the juice. How unjustifiable it is, therefore, to attribute, in every instance, the decay of timber to the albumen present in the sap, as if it was the only substance liable to spontaneous decomposition, or affording the vegetation of fungi and lichens!

In regard to the amount of sap and air contained in the oak and poplar, we possess the following data from Count Rumford:

	Wood.	Sap.	Air.
Oak,......................	0.39353	0.36122	0.24525
Poplar,....................	0.24289	0.21880	0.53831

The German botanist, Schacht, in all instances of decayed timber, has met with fungi and lichens. The destruction of timber by decay, after the same has been hewn, must, therefore, be considered as being produced by similar causes which brought on the disease of the vine, potato, mulberry trees, and other cultivated plants, which make the years 1845, '48, '53, '57 and others for ever painful to the memory.

That the juice should be in a state of decomposition before being capable of generating those organisms seems doubtful, since this has not been found the case in other and well-studied modes of fermentation. The morel, a species of mushroom, will also attack perfectly sound wood. Hand in hand with the spread of the fungi continues the decomposition of the ligneous tissue. Access to moisture and air, as also a certain degree of heat, are necessary. In regard to the air, fungi require oxygen for their generation. When air-dried, steamed, or chemically treated and afterward dried, wood commences to rot, it is a sign that moisture has again penetrated; for it is scarcely to be admitted, that in all these cases the sap had been entirely removed. Timber decomposes the easier the more sap it contains; and if green trees are hewn when the vessels are overflowing with juice, one may look with certainty for diminished durability of the timber. Timber is not always the more durable the more dense it is, but rather when the even fineness of the grain continues to the pith of the stem.

The Roman historian, Pliny, considers the resiniferous woods as the most durable. Indeed, nature shows that this is frequently the case. The resiniferous red and white pines of Oregon and California are considered first-class ship timber, so much so that entire vessels have been constructed from the denser qualities. The yellow or long-leaved pine, in dry situations, is extremely durable, and is preferred to oak of any kind, where a lighter, yet solid wood, is required. The white or northern pine, which grows abundantly in every northern State of the Union, from Maine to Minnesota, reaching often to an altitude of

one hundred and eighty feet, with a diameter of six feet or more, is said to retain its properties as long as the very best description of oak.

The proportion in which the woody fibre and water are to each other is very different. It varies according to the degree of dryness and the nature of the wood itself. According to Schubler and Neuffer, we have for newly felled woods the following table :

WOOD.	WATER.
Hornbeam,	18.6 per cent.
Willow,	26.0 "
Sycamore,	27.0 "
Ash,	28.7 "
Birch,	30.8 "
Oak,	34.7 "
Pedich Oak,	35.4 "
White Fir,	37.1 "
Pine,	39.7 "
Red Beech,	39.7 "
Alder,	41.6 "
Asp,	43.7 "
Elm,	44.5 "
Red Fir,	45.2 "
Lime Tree	47.1 "
Italian Poplar,	48.2 "
Larch,	48.6 "
White Poplar,	50.6 "
Black Poplar,	51.8 "

The amount of water in wood, after one year's drying in the air, ranges from 20 to 25 per cent., and when perfectly air-dry, as it is called, it still holds from ten to fifteen per cent.

The specific weight of newly felled timber ranges from 0.85 to 1.05 ; that of air-dried timber from 0.45 to 0.75. The weight of one cubic foot of newly cut

native timber would thus range from fifty to sixty-five pounds, while that of seasoned wood would vary from twenty-eight to forty-seven pounds. The total expulsion of moisture by means of air-drying, according to the experiments of Rumford, takes place only at 280° Fahrenheit. But even if thus completely dried, and then exposed again to the atmosphere, it absorbs nearly five per cent. of water during the first three days, and continues to absorb until it contains from fourteen to sixteen per cent., after which it becomes very hygroscopic, losing or absorbing water according to the state of the atmosphere.

The drying of lumber in confined rooms by means of hot air, or steam and air alternately, is now largely practiced, and the more on account of the economy of the method than on account of its yielding a superior product. In some cases; the wood, before being exposed to artificial heat, is subjected to a longitudinal pressure, in order to rupture the cells in which the moisture is confined, to the end that it may escape more freely upon the application of heat. It is claimed that the wood is thus rendered more valuable for nearly all the purposes for which it is used, but particularly for the hubs, spokes and panels of carriages, etc.

Preserving Wood.

The preservation of wood constitutes one of the most important questions with which applied chemistry has to deal. It has been ascertained by careful statistics that the wooden structures alone on the farms of this country cost over one hundred millions of dollars every year, while the sleepers on the rail-

ways cost twenty-five millions during the same period of time. If the duration of all this wood could be doubled, it would save the country twelve and a half millions every year in rail-road ties, and fifty millions in fence and farm buildings. At the same time, our woodlands are being cut down with fearful rapidity. This fact assumes great importance, when we reflect that there exists a most intimate relation between the climate of a country and the extent of its forests. This becomes at once evident, when it is known that the springs of rivers do not issue from subterranean reservoirs, but consist chiefly of collections of atmospheric precipitates, rain, dew and snow, which have percolated from higher levels. Rainless regions are always deficient in woodland, and there are innumerable instances where vast and fertile tracts of land have been changed into barren and unhealthy deserts, simply because they have been stripped of their forests. Therefore, in lengthening the duration of wooden structures, we, at the same time, prevent the destruction of our forests, thus leaving to the coming generations the same resources which we have inherited from our forefathers.

The process may be briefly described as follows: The wood to be treated is placed in an iron chamber, which is connected with a still containing coal-tar. To the latter heat is applied, until the contents have reached the temperature of 600° Fahr. The inventor not only claims that the thus impregnated wood will be completely protected against the moisture of the atmosphere, but also that it is rendered "nearly as indestructible as granite." In order to comprehend this process, it is necessary that we should examine

the nature of the products which are given off in heating coal-tar, and the changes which they produce on entering the pores of the woody fibre. Coal-tar consists, as is well known, of a number of substances—acid, basic and neutral; of the latter, some are liquid, some solid. In subjecting tar to distillation, the first products given off are ammonia and probably also permanent gases; then water is evolved, together with various ammoniacal substances, and a brownish oil of a noxious smell and of less specific gravity than water. The latter is associated with the so-called light oils, the portion in which they are contained being generally gathered separately in tar distilleries. They amount to from five to ten per cent., and when the temperature has reached 320° Fahr., it may be concluded that they have passed over. The oils distilling at a later stage contain large quantities of naphthalin and paranaphthalin, both solid hydrocarbons, of which the first appears at about 400° Fahr. They are often present in such quantities that the condensed distillate assumes the consistency of butter. Carbolic or phenic acid is given off a little earlier, but the giving off of naphthalized oils continues up to 550° Fahr., when a resinous, yellowish product appears, which can be easily kneaded between the fingers. The remainder is the black, pitchy mass, used in the construction of Nicholson's pavement.

Among the various substances here enumerated, the phenic acid alone is that to which any preservative properties can be ascribed. It has been determined that tar from cannel coal contains seven per cent., that of Staffordshire coal four and a half, and tar from Newcastle coal two and a half per cent. of

this acid. The average quantity of phenic acid in coal-tar would therefore be less than five per cent.; moreover, it is never found in the free state, but always in combination with bases, whereby its efficiency is greatly impaired. Again, being soluble in fresh and salt water, it is easily and rapidly washed out, finally leaving the wood as completely liable to decay, as well as to destruction by insects, as it was before treatment. These facts are sufficient to justify us in drawing the conclusion that the vapors of coal-tar are not efficient preservatives.

This fact was, indeed, particularly reported upon by the Dutch Government engineers. They discovered that after thirteen months' exposure, piles which had been creosotized under Mr. Bethel's special superintendence, were found so completely free from the impregnating material that the *teredo navalis* had eaten up and destroyed these to a thickness of one inch and a quarter. The same fact was also reported by Mr. Stevenson, the famous English engineer, in the case of the piles and wood-work on the Woolwich side of the Thames. The dead oil had been completely washed out, and the destruction of the wood by decay and by worms was proceeding at such a rate, that Mr. Stevenson expected to see the piles totally destroyed before the expiration of three years from the time when they had been impregnated.

Again, for many very important purposes this process is inapplicable, on account of the intolerably offensive smell of the dead oil and other products of the dry distillation of bituminous substances.

In a pamphlet before us, it is stated that there is no record in the books of any thing like this process

having ever been known to the world prior to its discovery by Mr. L. S. Robbins. It is claimed to be as new as was the sewing-machine or the telegraph. We presume that Mr. Robbins did not know of the process patented by Frantz Moll, in England, in 1835, which is as follows: The wood is placed in a close chamber, which is connected with one or more stills. The operation of impregnating is begun by heating the inside of the chamber by a steam pipe to a temperature sufficiently high to maintain the vapors containing the phenic acid in a vaporized state. But before these are introduced, the watery vapor from the damp timber is allowed to escape, after which heat is applied to the still containing the light hydrocarbon oils, or the "eupion," as the mixture was named by Moll. When it is thought that the timber has been sufficiently impregnated with these vapors, the surplus is drawn off, and vapors from another still, containing the heavy oils, are admitted into the chamber. Finally, boiling liquid creosote is introduced into the chamber by a pipe, in a quantity sufficient to cover all the wood therein. It will be seen that this process is substantially that of L. S. Robbins, but was recommended in 1858 by Dr. Krieg, in connection with soluble glass, for the preservation of all wood-work against fire and rot.

Wooden Roof Shingles.

One of the most valuable applications of the soluble glass may be recommended for shingles and wooden roofs of farm-houses in the country, and near rail-roads, where the sparks of the locomotives

have frequently caused conflagrations and destruction of property.

The operation is quite simple, and the expense but trifling; the process has already been described, but it may be still more simplified in the following manner:

After the steaming of the shingles in boilers or in tanks, where steam of 300 to 350° is led into them for several hours, they are dried and thrown into a weak solution of liquid silica, standing about 25° B., from which they are taken out and exposed to the air before they are quite dry, a weak solution of chloride of calcium is thrown over them or sprinkled over them with a broom; when quite dry they are fit for use. They will not burn nor be lighted by the sparks if exposed to a direct fire—will not light in a surrounding fire. An intense heat of long duration may char them on the surface; they are, however, quite safe against any inflammation.

Street Pavements.

As a rule, competent engineers express doubts as to the merits of the Nicholson, and of wooden pavements of all patterns.

In the Nicholson structure the road-bed is of sharp, clean sand, of the proper thickness. A basis is then made by laying common boards, dipped in hot coal-tar, lengthwise on stringers of like material laid from curb to curb. The blocks forming the superstructure are of Southern hard pine, three by four, and are set on end in rows, crosswise of the street—the blocks before setting being dipped to half their length in a

bath of coal-tar. Between the rows of blocks intervene pickets of thin board set on edge, and leaving an opening between the rows of blocks of an inch or nearly in depth. This opening is filled with clean screened gravel, rammed down with a paver's hammer, and an iron blade made for the purpose, and the surface is covered with hot coal-tar. The gutter exhibits its lowest point half a foot from the curb. The whole surface is covered with coal-tar sufficiently boiled to be tough and fibrous, but not brittle, upon which is sprinkled a layer of fine gravel and common sand. The Stafford pavement differs from the Nicholson, in the laying of large blocks prepared after the Seely patent, resting upon stringers, which in their turn may be supported by any specified road-bed. Provided the road-bed is sufficiently secure, say of strong concrete, and the upper deposit is made sufficiently complete, the Stafford pavement cannot but compare favorably with other wooden pavements, and, for simplicity, is quite superior to the Nicholson. The Stafford pavement appears, at the present moment, to be the favorite one in the City of New-York, as a large contract is now carried out for the upper part of the city.

Both obviate certain objections in surface way which pertain to the Belgian, in the wear and tear of vehicles and horses, and the noise or reverberation of wheels; but both are inferior to the asphaltic road in these respects, while the asphaltic has one great superiority valuable as preventive of accident, to wit, the beating of the hoof of the horse is rendered very audible—audible above all other sounds—so as to be measurable by the ear in the matter of distance. This

latter advantage can only be estimated by persons who have taken occasion to note the extent to which one falls into the habit of measuring the distance of a vehicle from any given crossing, by the ear; and one of the main liabilities to accident, occurring from wooden pavements, is the muffling or comparative muffling of the hoof beat. In this respect, in fact, any form of concrete pavement possesses material advantages over either the stone block, which exaggerates the rumble of wheels and obscures the hoof-beat, or the wooden pavement, which reduces both in about equal proportions. In a word, a grave objection to the Nicholson pavement is the fact, that in just one respect it is a trifle too noiseless for the safety of pedestrians in crossing, especially in these days when every driver seems to be possessed with the devil to run over some body. Again, in case of extensive conflagration in any part of the city, the wooden pavement might prove a dangerous ally by ignition, an instance of which has recently occurred in Philadelphia. Neither of the wooden pavements above named command the unqualified admiration of practical engineers as yet, though the test of use is the measure of merit in these matters, and neither has been in use here sufficiently long to warrant the expression of an opinion.

The Parisian system has, since 1854, manifested strong preference for the asphalt road upon the concrete foundation. In 1854, nine hundred and sixty square yards of asphalt road were laid in Paris, and since then the use of the material has steadily increased, until at present it is ranked as well adapted for purposes of heavy traffic on the most frequented thoroughfares. Up to 1866, 96,000 square yards had

been put down; in 1867 the surface added was 54,000 in Paris proper, and 84,000 in all in the department of the Seine, making a total in thirteen years of 180,000 square yards. The contract of the Cie Générale des Asphaltes with the City of Paris, covered at that date at least 96,000 square yards more, to be put down in 1868 and 1869. The ancient streets of Paris were without sidewalks, and were paved with large square blocks, with grades sloping from the sides to the middle, forming a gutter on the central line. Sidewalks began to appear in 1825, and in the same year the reversal of the surface, bringing the gutter to the sides, was introduced. In 1852 the system of MacAdam was applied to the old boulevards, and in 1858 this method was improved for heavy traffic by introducing margins along the sides, from two to four yards in width, paved with small blocks of Belgian porphyry—the germ of the sidewalk as now used.

The first cost of asphalt streets is greater than that of Macadamized, while the cost of repairs is considerably less; and, again, the first cost of the asphalt is less than that of the Belgian pavement, while the expense of repairing is greater. The asphalt coating, one-sixth of a foot thick, is supported upon a road-bed of concrete, composed of ninety parts gravel to forty parts of mortar, about a quarter of a foot in thickness, and resting upon the compacted soil bed beneath. Provided the requisites of thorough surface and under drainage have been observed, the asphalt roofing, being utterly impervious to water, the road-bed of concrete waxes harder and drier with age, and, once made, is imperishable. Repairs are easy, and consist simply in cutting away the damaged roofing of asphalt

and replacing it with new. As compared with the Belgian pavement, the liability to fall of horses being driven over the asphaltic road is 1 in 1,409 to 1 in 1,308 on the former, proving the superiority of the asphaltic surface in this respect—that is, in surety of foothold.

The merits of the wooden pavement are its noiselessness, its reduction of the mortality of horses, its reduction of the wear and tear of vehicles, and its effecting a utilization of the utmost per centage of draught force, and these are all merits to an equal degree of the asphaltic road, and may be made merits of any concrete whatsoever. The increased mortality in horses occasioned by the Russ and Belgian and other stone pavements in this city, is estimated at 3,500 annually—an item of considerable importance in the discrimination between pavements for thoroughfares. As between the two typical structures, the Belgian and the Nicholson, from data already supplied, it may be estimated that, with the attrition of Broadway, the former would last fifteen years against a last of half that period in the case of the latter, if, indeed, the Nicholson can be regarded as equal to the necessities of Broadway at all. It is seen, therefore, that while the stone block (Belgian or Russ) is open to grave objections on the one hand, the wooden pavements (Nicholson and Stafford) are open to equally serious objections on the other hand, on the score of lessened durability. The concrete pavement—the value of which has been happily settled in Paris—effects a union of the better qualities of both, without the objections appertaining to either; and, as the minds of engineers and inventors are already beginning to turn

in this direction, nothing is hazarded in predicting that the ideal or coming pavement will be developed from the present crude concretes. The asphalt road, one triumph of concretion, the *béton Coignet*, another triumph in a direction of equal practical importance, the attempts at concrete from inexpensive material in this country, all point to the hypothesis that the solution of the long mooted pavement problem is at hand, in the evolution of a concrete roadway combining the durability of the stone-block with the advantages of the wooden superstructure. Valuable hints as to the constitution of concretes may be found in the reports of Messrs. Beckwith on *béton Coignet*, and asphalt and bitumen as applied to the construction of streets and sidewalks in Paris; and, in the way of American invention, the constitution of the Fiske concrete pavement, under the Hairm Burlew patent, may be studied, but has proved so far a great failure in Fifth Avenue, where the concrete had to be taken up again last winter. This pavement is composed of gravel, broken stone, cinders and coal ashes, (free from all foreign substances,) mixed in definite proportions with tar, rosin and asphaltum. The road-bed properly prepared, the composition is spread on in layers of moderate thickness, successively rolled with heavy rollers for uniformity and compactness. These layers form a sufficiently strong roadway of from half to three-quarters of a foot in depth, and can be put down at an expense, per square foot, not exceeding the expense of the asphalt road as constructed in Paris. It remains for years and attrition to test the practical value of this concrete; but, in general, it may be remarked, that it is heartily and highly

commended by thoughtful engineers as a step in the right direction. The sonorousness of the hoof-beat, as enabling the pedestrian to measure the imminence of passing vehicles, is an element of concretes over wooden pavements, illustrated in an eminent degree by the asphaltic road, the value of which, as a preventive of accidents, cannot be over-estimated. A pavement may be too noiseless as well as too noisy for immunity in this respect, and by all means let the capacity of the concrete be developed to the utmost. The Commissioners of the Park have also developed some excellent roadways in their admirable system of earth roads upon a similar principle; though in relation to the Park, the problem has been less difficult of solution, no necessity existing to provide for the contingency of heavy traffic. In its capacity for the combination of all the qualities which experience has proved to be desirable in a roadway for large cities, the concrete must, therefore, be ranked as superior to either of its competitors, with some most important and indispensable improvements to be applied, and as embodying in itself the germ of the coming pavement in this city; and the suggested reforms in the sewerage system having been carried out, attention may be directed to the production of an inexpensive concrete, analogous to the asphaltic road.

Various Systems Adopted for Roadway Pavements.

A great variety of systems have been adopted for roadway pavements. The most convenient classification of them is into gravel compositions, broken

stone, plank, wooden block, cobble stone or pebble stone block and iron block pavements and tramways. The first attempts at pavements generally commence with the use of gravel. Roads thus made possess the advantages of cheapness of material and construction. In the Central Park, where there are probably the most perfect roads in this country, they have shown better endurance than those made on the MacAdam plan. Gravel roads, when properly constructed and maintained, are comparatively smooth and noiseless, besides affording excellent foothold for horses. The great objections to them are that they cannot be kept firm enough to afford easy draught for heavy traffic; that they lack, in a high degree, permanence, and are constantly requiring repairs; that they are difficult to keep clean and to drain properly; the rapidly grinding and crushing to powder tending greatly to cause dust in dry weather and mud in wet weather; and, lastly, that the best construction yet attained has failed to prevent them from washing into gullies. Under the head of second composition pavements, may properly be included pavements formed by the combinations of several materials, such as the famous asphalt pavement of Paris, concrete, *béton*, gutta percha, slag, cinder, and other pavements; also, those formed according to the experiments of McNeil, partly of broken stone and partly of pieces of cast metal, laid on a sub-pavement of rubble stone. The asphalt pavement of Paris, so often recommended in newspaper articles, is really quite an imperfect pavement. It is generally formed on a foundation of MacAdamized road. Powdered asphalt is placed on the foundation, and stamped with hot rammers until it is very hard,

and has a thickness of one or two inches. It is very pleasant and smooth to ride over, but requires most constant watching and repairing. It is slippery in wet weather, and excessively so at a freezing temperature.

Pavements of Granite.

Granite blocks, considered in every respect, form one of the most perfect pavements known. They are preferred, and almost exclusively adopted in London. The Russ pavement, the nearest approach to a perfect pavement yet constructed in this city, has, in imitation of the Roman pavement, a *béton* foundation of six inches thick. The *béton* is composed of one part cement, to two and a half parts of broken stone, and two parts of gravel. On this foundation are laid hard granite blocks ten inches deep, ten to eighteen inches long, and from five to twelve inches wide. It is very durable, and yet, as shown in Broadway, this excellent pavement has most signally failed, the surface of the granite used polishing and affording dangerous foothold. What is required, and this would give a perfect pavement, is the adoption of the kind of stone blocks used in London, which do not polish by wear, and present joints about every four inches. Another pavement is now being substituted here in an imperfect manner. The blocks now used are of a coarser granite, twelve inches long, nine inches deep, and four inches wide, the courses running at right angles with the line of the street. What is known as the Belgian pavement was, until recently, the principal one in use in the old streets of Paris, and, as is well known, has

been quite extensively adopted in this city. This pavement has the advantage of cheapness, and, if well laid, of economy, the necessary and actual cost being a little over one-half that of the Nicholson pavement. The final trouble, however, is their becoming polished and slippery, and hence they should not be laid in streets where they are subject to constant use.

Iron Block Pavements.

Several attempts have been made, with more or less success, to cast iron in blocks suitable for pavements. The chief objection is the cost of iron; but if properly laid, there can be no doubt of its being cheaper in the end than most other pavements. It has failed here on account of its inadequate and defective foundation, and on account of the principle employed of keying. The rings pressing on the sand foundation gave too little bearing surface, and any weight tended greatly to displace or overturn the block, which occurring, all the neighboring ones keying into it were released, and unless quickly repaired, the ruin of the whole pavement soon followed. It has stood much better in Boston, and for the simple reason of its being better laid It has stood there admirably, and shows no material signs of surface wear after ten or twelve years of constant use. It can be cast in such form as to give the best foothold for horses drawing heavy loads. It can be kept perfectly even and made smooth as the Nicholson pavement, and by its extreme hardness will give much less resistance to wheels. Being of uniform quality, all parts will wear equally, and as perfect a face will

always be presented as when new. Its smoothness tends greatly to lessen the noise, as this nuisance is caused principally by the boxes of the wheels striking against the collars on the axle, and of course increases with roughness of pavement surface. Iron, furthermore, loses but little from oxydation. It can be kept as clean as the Nicholson pavement, with the advantage of non-absorption. It has one great advantage, in being made so as to be easily and readily removed and replaced, the blocks formed from the same pattern being exact counterparts.

The Fiske Concrete Pavement.

This pavement is composed of seventy per cent. in bulk of broken stone, coal or gravel, clean coal or iron cinders, not over three inches in any dimensions. These are passed over a screen with meshes one quarter inch square. The coarser portion is then coated by mixing with tar, warm or cold, and then spread on the road-bed and heavily rolled until a depth of four inches is attained. The finer portion is then mixed with clean sharp sand, warmed, and then thoroughly mixed with tar, to which has been added rosin, carbojapanis or pitch. This is placed on the first layer of coarse material, and rolled until a depth of two inches is attained; after which the surface is covered with an excess of clean sharp sand, and again rolled.

The Nicholson Pavement.

We now come to the subject of wooden pavements. The first general attempt to use wooden blocks for

pavements took place some thirty years ago, both in this country and Europe. They are generally made in the form of hexagonal prisms of hard wood, laid directly on sand or earth. Leading off in the list of wooden pavements adopted in this city is the Nicholson pavement. In laying this pavement, the street is first prepared by a sufficient covering of sand, which is brought to the proper crown with a straight edge made for that purpose. This surface is then covered with common round inch boards, laid lengthwise with the line of the street. The ends of these boards rest on stringers of the same material laid from curb to curb.

Both sides of these boards are covered with hot coal-tar. The blocks are of Southern pine, three inches wide and six inches deep, and are set on end in rows crosswise of the street. Before setting, the blocks are dipped to half their height in hot coal-tar. Between each row of blocks, and at their base, pickets one inch thick and three inches wide are nailed on edge. The opening thus formed between the rows is filled with clean screened gravel, rammed with a paver's rammer, an iron blade made for that purpose, and then covered with hot coal-tar. The whole of the upper surface of the pavement, when laid, is covered with hot coal-tar, boiled to a consistency which, when cold, is to be tough, fibrous and not brittle, and then covered with fine gravel and common sand. After the top gravel has become packed on the surface and in the grooves, the street is swept.

The M'Gonegal Pavement.

This pavement, claimed to be an improvement on the Nicholson, to which it is similar, consists of a foundation of two inches of *béton*, on which are placed wooden blocks six inches deep, two and three-quarter inches wide, and from four to sixteen inches in length. Holes of one and a half inches in diameter, and three and a half inches deep, are bored in each block, and then triangular grooves formed on each side of the blocks, so that when two blocks are placed together, there will be a square opening one and a quarter inch square to receive a wooden dowel or key. The wood used for blocks and keys is prepared for preservation by Robbins' process. In laying, the blocks and keys are dipped in hot coal-tar. The perforations in the blocks are filled with clean roofing sand. The pavement is finished by a coating three-quarters of an inch in thickness of coal-tar and fine sand. These are the specifications as we have described them; but where this pavement has been laid in this city, a foundation of flooring of tarred boards has been substituted for that of *béton*.

The Stowe Pavement.

In constructing this pavement, which is also wooden, and a cheap form of the Nicholson, the street is first filled with sand, loam or loose earth, free from stones, to within about six inches of the desired street grade, but smoothed off so as to conform to the desired arch or crown of the street; then blocks of sound pine or spruce wood three inches in thick-

ness, and six inches in length, are set on their ends in a tier across the street, these blocks being cut square at both ends. A tier of blocks made wedge-shape at their ends by beveling on one side is set across the street close against the first tier of square-ended blocks, which are set up as before, and so on alternate tiers of square and wedge-shaped blocks are placed, until a space of ten feet or more is covered, then the wedge-shaped blocks are driven down into the sand or earth with rammer and swage until the foundation is of the required compactness. The cells or spaces between the three-inch blocks are filled with clean coarse gravel, not exceeding three-fourths of an inch in diameter, thoroughly driven with rammer and swage, then the gravel saturated with hot coal-tar, and the whole surface covered with hot coal-tar, and lastly, the pavement covered with fine gravel or sand.

The Brown and Miller Pavement.

This pavement is also similar to the Nicholson, only that its blocks are not set vertically, but at an angle of forty-five degrees, and rest on sills of a prismatic form, which, in turn, rest on boards placed five feet apart, and parallel with the line of the street.

The Robbins' Pavement.

This is another of the multifarious wooden pavements recently introduced in this city. It is very similar to the Nicholson, only the wood used is first prepared by Robbins' patent wood preserving process.

The Stafford Pavement

is only another imitation of the great original Nicholson. The blocks are dressed to a uniform thickness, grooved in the middle with a double dovetail, two and one-half by three-fourth inches, each side of the block beveled at one end, and running to an edge so as to form a groove on the upper surface.

Seeley's Concrete Pavement,

now being put down in Eleventh-street, near University Place, consists of sulphur, three parts; gas tar, twelve parts; silica (pebbles) sixty parts, by weight. The pebbles are heated 230° Fahrenheit before being mixed with the melted sulphur and tar.

General Directions for the Application of Silicate of Soda to Wooden Pavements and Cements.

The following method of application of the silicate is recommended by the author, and is reliable:

The planks and wooden blocks, intended as pavement, the size of the planks being from 10 to 12 feet in length and 1 inch in thickness, and the blocks from 10 to 12 inches square, and in the first place exposed the iron boilers to a temperature of 300° F. for several hours, or kept for 4–6 hours in boiling water, containing 2 per cent. of soda ash, which possesses the property of dissolving the albumen and sap contained in the cells of the wood, and by the boiling the coloring matter is extracted from the wood; when taken

from the boilers, they are brought in drying chambers of high temperature, and then removed to vats containing crude carbolic acid and tar water, standing for 6–8° B., which will enter into the pores, left open by the previous process, and a large portion of the liquid will be absorbed; from thence they are thrown into vats containing hot silicate of soda, standing 20° B., and left therein for 4–6 hours; they are then removed and dried either in air or hot chambers. When perfectly dry they are suitable for being put on a smooth ground, which may consist of a cement of silicated hydraulic lime or cement.

If strong cements, or lutes, where various other substances along with the dry silicate and metallic oxides are to be employed, the soluble glass is not diluted, but employed from 30–35° B., sufficiently to make a plastic composition; but where it is intended for mending or filling cracks or holes, either in stoves or iron castings, discretion of the consistency of the mass must be used, as it may be more advantageous for the cement to dry slowly, so as to prevent too sudden a contraction.

For painting or coating on stone, it is useful to apply the dilute by a syringe, and if necessary, repeat the operation 2–3 times after each drying. For preserving monuments, tombstones, marble columns, etc., the dilute silicate of soda may be used as a wash, with or without the addition of baryta, (the precipitated sulphate of baryta is always preferred, although expensive,) lead, zinc or limewash, by means of a paint brush, and according to the condition of the stone as to porosity. If the chloride of calcium, chloride of iron, or dilute hydrofluoric acid are applied upon the

surface of the stone, cement or paint, they are thrown over the silicated surface uniformly, so as to cover every part of the material to be treated. In all cases it is understood that the silicate application is to be applied on new stone, for it will not adhere on old paint; therefore, if it is to be used, it is indispensable that it be first removed by soap, caustic alkali, spirits of turpentine, or even acids, and when perfectly clean and dry, the operation of silicating may take place. In all cases where the substances are to be painted or undergo a silicification, it may be repeated 2–3 times, at each interval of at least 12 hours; a weak hydrofluoric acid may in all cases be used as a wash over the silicated stones; 1,000 square feet of wall covering can be executed with 200 gallons of dilute silicate of either soda or potash. In diluting the silicate, it is well to employ 3 applications of various qualities, such as, for instance, the first coat may consist of 1 part of silica to 2 parts of water, and another of equal quantities of water, and the last coat the dilution to be 1 part of water.

For Preservation of Walls.

It is well known that brick absorbs its weight of moisture and requires much attention. The external surfaces of the walls to be protected are first washed with a silicate of soda, which is applied again and again, until the bricks are saturated, and the silicate ceases to be absorbed. The strength of the solution is regulated by the character of the bricks upon which it is to be applied, a heavier mixture being used upon porous walls, and a lighter one on those of denser

texture. After the silicate has become thoroughly absorbed, and none is visible upon the surface, a solution of chloride of calcium is applied, which, immediately combining with the silicate of soda, forms a perfectly insoluble compound, which completely fills up all the interstices in the brick or stone, without in any way altering its original appearance. By this operation the wall is rendered perfectly water-tight, and, as the pores of the bricks are thoroughly filled for a considerable depth from the surface with the insoluble compound, which is entirely unaffected by atmospheric influences, no subsequent process is necessary.

THE PROTECTION OF RAIL-ROAD SLEEPERS, CROSS-TIES, FRAME HOUSES, TELEGRAPH POLES, TIMBER, STAVES, SHINGLES, LATHS, TANKS, TUBS, CASKS, BARRELS, (Petroleum, Naphtha, Spirits Turpentine, Alcohol, Linseed Oil,) CISTERNS, AND EVERY DESCRIPTION OF WOOD, AGAINST FIRE, DRY ROT AND LEAKAGE.

The seasoning or initiatory preparation of the lumber, so as to destroy the organic or nitrogenized matters enclosed in all the cells of vegetable matters, are dissolved and washed out of it; or, in other words, the removal of all the albumen, sap and coloring matter, is effected by exposing from four to six hours to boiling water, containing about one per cent. of soda ash in solution. They are then withdrawn and dried in hot rooms, and then thrown into tanks containing the tar and carbolic acid water, and left for a few hours, then dried again and thrown into a hot solution of silicate of soda, standing 20° B., in which they

are left for ten or twelve hours. When removed from here a weak limewash is applied with a brush or sponge, consisting of 10 lbs. slaked lime to 40 gallons of water, when likewise they are removed to a dry or hot air; after that a weak wash of chloride of calcium is thrown or brushed over them when nearly dry. The process is then finished, and the articles so prepared will resist the elements as above stated. They increase in weight by this process about 6 per cent. After this treatment, they assume upon the first drying a glazed appearance, and the pores are filled with insoluble silicas precipitated by the action of the tar liquor upon the alkali of the silicate of soda. Barrels which have been treated may be rendered perfectly impervious, by filling up the chimes (the inside of those barrels having been treated with the silicate of soda and chloride of calcium) with a thin silicated cement applied on the interstices. No air nor any liquid will then have any effect; the lightest liquid may then be kept in those prepared barrels without escaping; flour, butter, lard, and many other perishable substances may be kept for a length of time in barrels so prepared. Spirits of turpentine, linseed oil, alcohol, and other spirituous liquors, may safely be transported and kept for a length of time, without evaporation or loss in the contents of the barrels. *Telegraph poles*, which are from twenty to thirty feet long, require a different treatment for their seasoning before they undergo the silicification. They are steeped first in the tar carbolic liquid, in holes dug in the ground with tanks built in the same, and left in there for several days; then taken out, and undergoing the other process of silicate of soda, limewash and chloride of calcium, as described, will render them proof against fire and dry rot.

The Silica Cement, a Preservative to the Bottom of Iron Ships.

It is well known that iron ships have produced many disasters from rusting after long voyages; the experiments tried for preventing the adherence of barnacles and the rusting have been very numerous. The author feels quite confident of success, by the proper application of a silica cement prepared by a hot solution of asphaltum and fine sand, manganese and liquid silicate of soda, and putting it on the bottom of the iron ships by means of a brush, and before becoming quite dry, to dust over the paint more powdered manganese.

The Most Adhesive Lubricator.

Black lead, 6 lbs., are mixed with 3 lbs. slaked lime; 8 lbs. sulphate of baryta are mixed with 7 lbs. of linseed oil; the whole mass is well mixed together to a uniform consistency, and the entire mass made more plastic with concentrated solution of silicate of soda. This cement may be used for numerous purposes, where hardness and adhesiveness are the desired objects, uniting at the same time steam and hot water. For locomotives, engines and machinery it is prepared from a mixture of silicate of soda liquid, at 25° B., added to fine plumbago, talc and asbestos in equal quantities, so as to retain the thin plastic condition, and capable of dropping it on the journals in very small portions.

The Cheapest Whitewash, which is very durable for indoor and outdoor work, is prepared by the fol-

lowing composition : To 1 lb. slaked lime and 1 lb. sulphate baryta, add 1 pint of silicate of soda and 1 pailful of hot water ; stir the materials well together, and use it at once. If the color is intended for a yellow wash, add a quarter of a lb. chrome yellow ; if for a blue wash, use instead of the latter a quarter of a lb. of ultramarine, (worth six cents ;) and if the paint is intended to coat iron railing, stoves, steamboat chimneys, and to obtain a brown or black fire-proof paint, add half a pound of manganite, an oxide of manganese, or the pyrolusite, which is the black or gray peroxide of manganese.

The white wash or yellow wash just quoted is extremely durable and cheap for wooden fences along rail-road tracks, canal boats, farm houses, and other wooden structures.

The Most Durable Aquarium Cement.

The materials of a water-resisting composition are prepared by mixing finely powdered dry silicate of soda, powdered chalk, and fine sand in equal quantities, made plastic with the liquid silicate, and applied at the joints, and worked over with fluid chloride of calcium, and when quite dry let some weak hydrofluoric acid pass over the cemented joints. This cement will be permanently impervious to water, and will not crack. The same composition is quite suitable for breweries, malt houses, linings for water-tanks, and cellars into which water flows.

The author considers it advisable to show, also, the advantages of concrete, by quoting Tall's system, applied in Paris, and the description of the concrete

bridge at London, and will state, that the addition of silicate of soda to the concrete will undoubtedly ensure a great saving.

The material consists of one part of Portland cement to eight parts of coarse gravel. The cement and gravel are first well mixed together in a dry state, and when this is done it is damped by means of a large watering pot, containing some hot silicate of soda, and again mixed by a pronged drag, such as is used for dragging dung out of a cart, until the entire heap has been wetted and mixed together. It is then put in iron or zinc pails and poured into the frame, where it is leveled by men stationed for the purpose. In order to save concrete, large lumps of stones or brickbats are put into the centre of the wall, and covered over and about with concrete. Frost does not affect the concrete after it has once set, which, with good cement, will be in about five or six hours. Nor do heavy rains appear to injure it in the slightest degree, though they may chance to fall ere the concrete has hardened. The walls can be made straight and even as it is possible for walls to be, and the corners as sharp and neat as if they had been formed of the most carefully dressed stone.

The Soluble Glass as Manure for Grapevines.

By putting the dry silicate of soda at the roots of grapevines, with or without the addition of phosphate of lime, has, by experiments, proved of immense benefit to the thriving of the vines to a proper thickness, and the grapes of uncommon size.

The Soluble Glass a Substitute for Glue.

It has proved quite useful in applying the liquid glass for glueing wood and paper together, instead of the common glue, and it is sold in the trade as mucilage, and applied on pasteboard instead of emery or corundum paper, used by cabinet-makers and other mechanics for polishing. As a paste for book-binders instead of glue, starch or dexterine, it has proved quite useful. Earthenware may be kept more durable by lining them with a weak solution. It is likewise used on leather, provided the same is not exposed to much bending.

The *glazing or enameling of culinary vessels*, made either for iron or stone ware, the soluble glass is usefully applied in the following manner:

The silicate solution of soda and potash is mixed with thick lime water; to 100 parts of the silicate add 1 part of lime water, made from 1 part caustic lime to 6 parts of water. The mixture is then evaporated to dryness and reduced to fine powder. By dipping first the objects to be glazed in the liquid silica, the powder is then sifted over them; when dry, the operation is repeated again; when dry, the coating becomes so hard that it cannot be rubbed off by the hands; they are then treated like other ware by putting them in a furnace, requiring, however, not a very great heat.

A similar process is to prepare a mass from 100 parts powdered quartz, 80 parts pure potash, 10 parts saltpetre, and 20 parts slaked lime, which mixture is made into a thin paste with the liquid silicate, and then burnt. This glazing is very durable, and resists

both vegetable and mineral acids like common glass. It requires no great skill to execute the operation, and the expense to prepare such a glazing is but a trifle.

Soluble Glass Application for Various Cements.

Porcelain, Glass and Metals are fastened together when broken, either by the liquid or gelatinous silicate by the following method: Heat the object to be fastened together to that of boiling water, and apply the soluble glass on both sides of the fracture, press them together and leave them in a warm place for a fortnight, when they will be fit for use. Fluorspar finely ground, black oxide of manganese, oxide of iron, (crocus,) finely powdered soluble glass, and many more refractory substances are suitable articles to mix with the liquid silica for the various cements in use. A cement for fastening iron in stone, glass or wood is recommended, consisting in 1 part prepared chalk, 1 part marble dust, and made plastic with the liquid silica, or 1 part powdered soluble glass, 2 parts powdered fluorspar, made into a paste with the liquid silica, and this is for pasting labels on glass bottles.

Caseine, or metamorphosed milk, is also mixed with the liquid silica, and makes an excellent paste.

Fireproof Cement is composed of the various oxides of iron, and formed into a paste with the liquid silica.

The Athens Marble Cement is composed of carbonate of lime, carbonate of magnesia and silica with oxide of iron, and made into a thin liquid and applied to the stone, which, on drying, is permanently fastened

to the surface, and protects it from smoke, dust and atmospheric agents.

Common and fire brick acquire great strength if the silicate of soda has been employed in the manufacture, and become indestructible; they are then particularly fit for bakers' ovens, wall and well foundations and furnace beds.

Glazed Paper for apothecaries' use, may likewise be prepared with the soluble glass.

Metallic Cement is formed of a mixture of equal parts of oxide of zinc, peroxide of manganese and litharge, and made up with liquid silica and marble dust, and applied between the metals to be cemented.

An Impermeable Cement Resisting Steam.

It is prepared by mixing six parts finely powdered black lead, 3 parts slaked lime, and 8 parts of Plaster of Paris, made into consistency by the liquid silica.

Zinc Cement, for stopping cracks in metallic apparatus and other materials, is made by mixing equal weights of zinc white and finely powdered soluble glass with a solution of chloride of zinc of the density of 126; it sets rapidly and resists the action of most agents. The simple mixture of oxide of zinc with a solution of the chloride of zinc, has also been recommended.

The Gypsum and Clay Cement.

This cement is very hard, and is prepared by an intimate mixture with liquid silica, after the gypsum

has been calcined, and it is preferred to lime cement, for the reason that by the action of fire, it becomes reconverted into lime, which, when the water from fire engines is brought to bear upon it, expands much, and forces out the walls to the destruction of the walls.

Hard Cement.

It consists in mixing 5 parts powdered clay, 2 parts iron filings, and 1 part of black oxide of manganese, and ½ part borax, made into paste with liquid silica; when dry is very hard, and withstands water. Also, a *mixture of manganese and zinc white* with Plaster of Paris forms a very hard cement, and has great adhesive capacity.

Drain and gas pipes, for conducting to sewers and houses, may be made as permanent as iron pipes by using a hard cement, consisting of hydraulic lime, clay and sand, mixed with fine powdered fluorspar and soluble glass, all made plastic by the liquid silica; this mass, when dry and burnt, will resist a pressure of 600 pounds to the square inch, while iron pipes burst under a pressure of 400 pounds to the square inch.

Cement for Closing Cracks in Stoves.

It is prepared by mixing finely pulverized iron, such as can be procured at the druggists, with liquid water glass, to a thick paste, and then coating the cracks with it. The hotter the fire, the more does the cement melt with its metallic ingredients, and the more completely will the crack become closed.

Cement for a Cistern.

Take	10	parts of	Plaster of Paris.
"	2	"	Glauber Salts.
"	4	"	Clay.
"	4	"	Slaked Lime.

Made in a plastic cement with the liquid silicate of soda, and, before it hardens, add liquid chloride of calcium.

For sweetening the water in cisterns, which is found to be hard, may be made soft by one gallon of silicate of soda in the cistern, and repeat the operation once a month.

The best iron cement is composed of calcined plaster and iron filings, from each 10 parts, 4 parts oxide manganese, 2 parts slaked lime, made plastic with the liquid silicate of soda.

A Strong Cement for Iron.

To 4–5 parts clay, dry and powdered, 2 parts iron filings, 1 part manganese, ½ part salt, ½ part borax, in a paste made with soluble glass, or equal parts zinc white and manganese, made to a paste; must be used immediately.

The Peasley Cement.

The manufacturer of this cement has made himself celebrated and wealthy by his perambulations throughout the United States with a span of horses attached to a load of hay, so it is thought advisable to enlighten the reader with its composition:

White glue, dissolved in a large quantity of hot water, also 50 parts of isinglass, and 3 parts of gum

arabic, and 3 parts of gum tragacanth, and to this solution an alcoholic solution of white shellac; 1 part of the latter is then mixed with the watery solution. To the whole are added 24 parts of white lead, and 12 parts of glycerine, and 200 parts of alcohol. It is immediately put in bottles and well corked. In other words: 200 parts white glue, 24½ parts lead, 12 parts glycerine, 200 parts alcohol, 50 parts isinglass, 3 parts gum arabic, 3 parts gum tragacanth, 1 part bleached shellac.

Iron Cement for Water and Gas Pipes and Castings.

It is obtained from sixty parts cast iron turnings, mixed with two parts of sal ammonia, one part fluor sulphur, and one part lime cement; the whole made plastic by the liquid glass just before using it, to mend holes of whatever description in iron pipes or iron castings; it becomes soon very hard, and every crevice is filled.

Cement with Liquid Silica for all Purposes.

A good cement, which will stand for many years without any paint. Good Portland cement is always recognised by its bright color of bluish tinge, but a common cement is of a dull slate color. For face work, two of gravel and one of cement is the best mixture; with the finishing coat, half and half; too much cement in the mixture makes it too rich, and is a common cause of cracks; good cement should become hard the second day, so as not to be easily broken; that which will crumble in the fingers on the second day must be condemned at once.

Cement intended for mouldings should be mixed with sharp sand, or a smooth finish cannot be obtained. Portland cement, gravel made plastic with the liquid silica, ought to be used only as the first coat, but not on the finishing coat; if rain gets to it before being quite dry, it is very liable to perish.

Stone Cement.

Infusorial earth one, and litharge one, equal parts, fresh slaked lime one-half, and linseed oil, made into a homogeneous mass, assume the hardness of sandstone, suitable to fasten iron in stone, such as fountains, vases, statuary, and in small quantity, may be used.

Colored Cements.

To a solution of silicate of soda of 1.298, add, while stirring, first pulverized and previously washed lixiviated chalk, so as to form a thick mass, to which are added for coloring purposes the following substances:

For black, sulphuret of antimony.

Gray, iron filings.

Gray white, zinc dust.

Bright green, carbonate of copper.

Blue, orange and red, cobalt, vermilion and carmine.

This cement hardens in six to eight hours, and bears polishing like marble.

Coating for Outside Walls.

The following coating for rough brick walls is used by the United States Government for painting light-

houses, and it effectually prevents moisture from striking through: Take of fresh Rosendale cement three parts, and of clean, fine sand one part; mix with fresh water thoroughly. This gives a gray or granite color, dark or light, according to the color of the cement. If brick color is desired, add enough Venetian red to the mixture to produce the color. If a very light color is desired, lime may be used with the cement and sand. Care must be taken to have all the ingredients well mixed together. In applying the wash, the wall must be wet with clean fresh water; then follow immediately with the cement wash. This prevents the bricks from absorbing the water from the wash too rapidly, and gives time for the cement to set. The wash must be well stirred during the application. The mixture is to be made as thick as can be applied conveniently with a whitewash brush. It is admirably suited for brick-work, fences, etc., but it cannot be used to advantage over paint or whitewash.

Preservation of Stones.

Dr. Robert, in the Paris "Les Mondes," maintains that the use of the black oxide of copper, and its salts, will effectually prevent change in stone. He shows that the decay of granite, marble, limestones, sandstones, and all natural building stones, is the combined effect of various causes, and that among these is a very minute lichen, the *Lepra antiquitalis*, which is one of the worst enemies of stone, and its action is to such an extent that, for instance, the beautiful marble sculptures of the well-known Parc de Versailles will, unless proper measures be taken for stay-

ing the process of decay, be unsightly and ugly masses of dirt, and quite irretrievably lost, as works of art, within the next 50 years. The author, taking as instances such buildings at Paris as the Bourbon Palace, the Palais du Corps Legislatif, the Mazarin Palace, (*l'Institut*,) the Mint, and others, points out that dust, spiders' webs, and the action of rain, combined with the minute lichen above alluded to, hasten the decay of stone, especially of those parts where any sculpture or ornamental carving promotes the deposition of dirt and dust. Various places and instances are cited of the application of oxide of copper and its salts, which places are open to inspection; and the length of time which has elapsed since such application, seems to warrant the conclusion that these compounds act as preservatives of stone. In reference to granite, the author states that this stone is also, according to the experience of Egyptian engineers, far more readily affected by a moist climate than one would be led to believe. The obelisk of Luxur, brought from Upper Egypt to Paris, has become blanched and full of small cracks during the 40 years it has stood on the Place de la Concorde; although 40 centuries had not perceptibly affected it as long as it was in Egypt. Granite in a moist climate becomes the seat of a minute cryptogamic plant, which greatly aids its destruction; and it is, moreover, a well-known fact, that the disintegration of this stone, which is composed of three separate minerals, (quartz, mica and felspar,) depends very greatly upon the thorough and intimate mixture, as well as the chemical composition, of these three ingredients, each of which, in a separate state, more easily withstands the influence of the weather.

Preservation of Stone by Silica.

The Victoria stone seems to have endured severe tests and to promise well. The process by which it is made consists in mixing broken granite with hydraulic cement, and steeping the whole, when set, in a solution of silica. The granite used is the refuse of the quarries, and is broken up at the works. It is then mixed with Portland cement, in proportions of four of granite to one of cement, sufficient water being added to give it a pasty consistency. In this state it is placed in moulds, when it consolidates in about four days. When taken from the moulds it is placed for two days in a solution of silicate of soda, which completes the process.

The silicate solution is prepared in a peculiar manner, and upon it the success of the operation depends. The silicate of soda has the property of hardening any kind of concrete in which lime is a component. This substance has been hitherto too costly for general use in artificial stone manufacture, and it becomes caustic by the absorption of its silica, so that it attacks the hands of the workmen.

A Strong Metallic Cement.

It is intended to cement or unite metals together, and which hardens rapidly; may be made by stirring the finest Paris white in a solution of silicate of soda at 30° B., so as to form a plastic mass, which may be colored by the oxide of manganese, or sulphuret of antimony, or iron filings or zinc dust. Carbonate of copper gives a green color, oxide of chrome a dark green, red lead an orange, vermilion a scarlet, and

carmine a violet color. After the application between the metals to be joined, the cement may be polished, and acquires a metallic lustre. It may also be employed for the permanent repair of zinc ornaments.

The Latest Chinese Waterproof Composition.

Schoicao is a composition used in Pekin for covering straw baskets, which are intended to carry oil for long distances. Cardboards, when covered with it, become as hard as wood. Most wooden buildings in the capital have a coating of it. The original was made of 3 parts of blood deprived of its febrine, 4 parts of lime and a little alum, and by adding 2 parts of liquid silicate of soda, will improve the mass very much.

The most refractory cement is formed from silica, asbestos, plumbago and soapstone. These materials, mixed in certain proportions and made plastic by the liquid silica, form a most valuable cement for locomotive journals and other lubricating purposes, for lining of steam boilers as well as coating, for filling up airholes in iron castings. By the addition of peroxide of manganese, it may be much improved, and serve as a permanent paint, which is fire and waterproof.

ARTIFICIAL STONE.

The following notice of artificial stone has been taken from the Report of the U. S. Commissioner to the Paris Exposition of 1867:

The agglomerated *bétons* have been extensively introduced in France in the construction of heavy public works, and in the erection of private dwellings. Nearly forty miles of the sewers of Paris have been constructed wholly of this material. All the foundations and basements of the palace of the Exposition, and other heavy structures in the Champ de Mars, those of the immense military barrack recently erected on the island of the city, the rail-road bridge of Ste. Colombe on the road from Lyons to Marseilles, a very large number of substructures for private houses, some houses entire, and innumerable foundations for the support of heavy machinery, have been constructed in the same way.

The manufacture, as now generally practiced, was originated by Mr. Coignet, a French engineer, whose name is generally associated with the process. The following particulars in regard to the Coignet *béton* are gathered from several sources, the most interesting being derived from a paper on the subject, published by Mr. A. Paul, civil engineer, of Paris.

This substance is compounded of sand in large quantity, with lime in smaller, say in the proportion of five

to one, more or less, and also, if rapid setting and unusual hardness are desired, with a quantity of cement, hardly more than one-quarter of the quantity of lime, the proportions being estimated by volume and not by weight. This mixture, in a condition nearly dry, and reduced to the form of a stiff paste, by being ground and worked up in mills constructed for the purpose, is introduced into the moulds designed to give it form, and compacted by repeated blows of a heavy rammer. The result is the production of a copy firm enough to allow the removal of the mould at once, by the separation of its parts. The copy is perfect, since the yielding material, under the heavy impact of the ram, has been driven into all the minute lines of the mould, and all the delicate traceries of the ornamental work. On exposure to the air the block rapidly hardens, and it has soon all the solidity of natural stone.

The effect of the successive processes of grinding and ramming is singularly to increase the specific gravity of the product. The reduction of volume, when the bulk of the compacted mass is compared with that of the materials out of which it is composed, is nearly as two to one, (1.7 to one,) and the weight per cubic foot becomes about one hundred and forty pounds. Simultaneously with the increase of weight, there occurs a very remarkable increase of strength; the resistance of many specimens to compression amounting to more than two and a half tons to the square inch.* An ordinary mortar, made with precisely the same materials,

* Specimens of very superior bétons have even resisted crushing pressures approaching to four tons per square inch of section.

will be crushed by a pressure of probably less than five hundred pounds.

The explanation of this greatly increased cohesive strength may perhaps be found in the following considerations:

In mixing mortar an excess of water is always employed, and this occupies much space, and by separating the molecules of lime prevents their union, or acts unfavorably to what is called the setting of the mortar. If we suppose this setting, in the case of lime or cement, to be an actual, though perhaps confused, crystalization, whether of hydrate of lime, or of the silicate and aluminate of lime, mixed or combined, which constitute, in different proportions, hydraulic limes and cements, it follows that this crystalization will be so much the more energetic in measure as the water present in the mortar in excess during the preparation is more effectually eliminated, and that in the same proportion the union of the sand, lime and cement will be more intimate.

It is the opinion of the engineer whose paper has been cited above, that the hardening of the compacted mass is not exclusively due to the physical properties of the lime and cement in their original condition, but is owing also, in a measure, to the conversion of these substances gradually into carbonates, and that this conversion goes on the more rapidly and becomes the more complete in proportion as the lime is more finely divided.

Hydraulic lime should be used in this preparation. Fat lime may be employed, provided that a sufficient proportion of cement be added to give it the hydraulic character. The lime should be well burned; lumps

which seem to be overburned or underburned must be rejected. It is slaked by sprinkling, and afterwards heaped up and allowed to lie some days in order that it may acquire its maximum of volume and become thoroughly disintegrated. It is then sifted through No. 35 wire gauze. In this powdered condition the slaked lime may be kept for lengths of time.

It has been proved by the inventor, Mr. Coignet, that all kinds of lime, even the most common, after a while become as hard as the best. The only difference is in the promptness of the setting. In explanation of this fact, it is suggested that the ultimate hardness is probably due to the formation of the carbonate.

The cements employed in the manufacture of these *bétons* are in general the heavy and slow setting cements. The sand preferred is river sand, mixed with particles of stone of from one to five millimetres in diameter. If the sand is too coarse, the resulting masses will be rough; if too fine, it separates too much the molecules of the lime, retards the setting, and is prejudicial to the strength and durability of the resulting product. Pit sand answers very well; but in order to produce a result equal to that obtained with river sand, it is necessary to increase the proportion of lime and cement.

In mixing the materials, they are rudely measured, spread out on the ground, and turned with a shovel until the mass becomes homogeneous. They are then introduced into a tempering mill, and subjected to a very energetic grinding; water being added sparingly from time to time, and only in sufficient quantity to give the mass cohesiveness, and bring it to the form of a paste as stiff as can be conveniently worked. The

importance of this part of the operation is very great, since the rapidity of the setting and the degree of the ultimate hardness will depend upon the minute subdivision, which is the effect of the grinding in the mill of the particles of lime and cement.

The tempering mill is one which has been constructed specially for this purpose. It is of rolled iron, cylindrical in form, and has a vertical arbor in the centre, armed with knives set spirally around it. At the bottom, the cylinder is perforated with many holes, through which the material is expelled by the pressure of a cycloidal appendage attached to the arbor below the knives. The rapidity of the expulsion may be controlled by raising or depressing a cylindrical gate, resembling the gate of the Fourneyron turbine, the process being retarded as the number of holes uncovered is diminished. As the tempered *béton* is expelled in the plastic condition at the bottom, additions are made to the quantity in the mill by introducing raw material at the top.

The plastic *béton* thus obtained is thrown into the moulds in strata of from one to three inches thick, and beaten down and compacted by repeated blows of a heavy ram, weighing from fifteen to twenty pounds, applied all over the surface. The beating of a stratum having been completed, its surface is scratched and roughened by means of a rake, for the purpose of forming a secure bond with the stratum next to follow.

Two kinds of moulds are employed, according as the object moulded is to remain permanently in the spot where it is formed, or is to be removed and built into a structure elsewhere. In the first case, the moulds are a species of coffer built up temporarily of wooden

walls united by horizontal cross-pieces, which are secured by bolts. To the interior of these coffer walls may be affixed the moulds necessary to produce architectural forms, or the ornaments and decorations of staircases, portals, windows, &c., so that entire walls may be built in mass, with every appearance of being sculptured out of stone. For the preparation of portable blocks, the moulds are more varied in construction. They take the form of every description of object of which stone is the usual material, and serve to produce vases, urns, busts, statues, or simple cornices and friezes.

The following proportions are given by Mr. Paul as those employed in the great monolithic structures of Paris, including the sewers and the substructures of the Exposition, viz.: five parts of sand, one of lime, and one-quarter of one part of cement in bulk. Such is the rapidity with which constructions in this material are carried on, that in six or eight hours after beginning work on a given length of sewer, it becomes safe and practicable to remove and advance the centres; and in four or five days after a section has been completed, it may safely be turned over for use.

For arches with a pitch of one in ten, the proportions are, for the sand and lime the same as given above, but the quantity of cement is doubled. The groined arches of the ventilators of the Exposition, and of the substructures of the gallery of refreshments surrounding the Exposition palace, were constructed to this pitch, and thus a floor of vast dimensions was supported by isolated columns one foot in diameter and distant ten feet from each other in all directions. At the crown of the arches this floor was but a little

more than five and a half inches thick. The span of the basement arches of the city barrack is nearly twice as great, being 18.3 feet, and these arches are built to the same pitch. At the crown, in this case, the thickness of the material is nine inches. One month after the completion of one of these it bore a weight of forty-eight thousand kilograms upon twelve square metres of surface, or of forty-eight tons upon a surface of ten feet by twelve.

A church has been constructed at Vésinet of this material entirely, the whole being a mass of *béton* without joints. The pit sand of the neighborhood was used, and the lime and cement were in the proportions first given above. But the pavements were made of a *béton* richer in cement; the quantity of this ingredient being made, for this part of the construction, equal to that of lime. These pavements were very carefully rammed and smoothed with the trowel. In the lumber mill of Aubervilliers, the arches of the substructure, built of the Coignet *béton*, are twenty-eight feet in span and fourteen inches thick at the crown. All the machinery of the saws is firmly fastened to the floors formed by these arches, by means of cramp-irons secured with lead, without having occasioned any injury to the structure during all the time the mills have been in operation.

The most important of the benefits which are to result from the use of the agglomerated *bétons* is probably to be looked for in the superior stability and strength which they are destined to give to the foundations and basements of ordinary dwelling-houses. The usual mode of forming such constructions at present is to employ a certain amount of cut stone at inter-

vals, and to fill up the intervening spaces with rubble masonry. The entirely dissimilar character of these two kinds of masonry, with the great number of bonds or surfaces of junction between them, produces unequal settling and the consequent cracking of the walls. Walls which are constructed of agglomerated *béton* are not liable to such accidents. Their whole mass forms but a single homogeneous block, stronger than even the rock on which it rests as a foundation. From the fact of their continuity, their weight is distributed over the entire area of the foundation, and no settling can take place so unequally as to produce fracture.

In a dwelling of five stories, in Miromesnil-street, Paris, constructed of a single mass of *béton*, a staircase of the same material runs in helicoidal form from the basement to the highest floor, moulded in the position where it stands.

At the Paris Exposition of 1867, there were presented specimens of the various applications of this important material, including a pavilion, as illustrative of its adaptedness to building in mass, lintels, cornices, friezes, paving slabs, troughs, garden benches and tables, vases, monuments, urns, statues and nearly every other important object in which stone is commonly employed, whether for useful or for ornamental purposes. As scarcely ten years have passed since Mr. Coignet's first experiments were made, and as it is only within the last two or three that the process has been perfected, or at least that its merits have been recognised, the *béton aggloméré* must be regarded as one of those new and useful things which the Exposition of 1867 was first to bring conspicuously before

the world. At the Exposition of 1862, the efforts which, up to that time, had been made in this direction, inspired in the jury in charge of the subject so little confidence, that the report of that body disposed of them all in the following summary manner: "Many artificial stones which at first sight appear admirably adapted for this purpose [building] are found, when exposed to this unerring test, [actual experience of some years,] to be utterly wanting in durability. No artificial stone can, therefore, be considered durable as compared with natural stone until it has undergone the test of long experience;" a test which the jury were not disposed to think had as yet been satisfactorily sustained by any such composition known to them.

The crushing weight which the *béton* of Mr. Coignet is capable of resisting has been stated at four hundred kilograms per square centimetre, or nearly fifty-four hundred pounds to the square inch. Its resistance to a force of tension is thirty to forty kilograms the square centimetre, or four hundred to five hundred and forty pounds per square inch.

Experiments at Marseilles and at Cherbourg.

The results, on the whole, are interesting and suggest the following conclusions:

1. Common lime can be substituted for hydraulic lime in béton-coignet, with an equally durable result, provided the blocks are allowed to harden for a few days on land previous to immersion.

2. Blocks of béton-coignet (sand and hydraulic lime) can be made in direct contact with the sea, provided

they be protected by a crib during the time necessary for the taking, say 24 hours. Blocks thus made have proved as durable as those made on shore; while under similar circumstances of immediate immersion in the sea, and 24 hours' protection by a crib, blocks of ordinary concrete (sand, hydraulic lime, and stones) made with the same hydraulic lime, would disappear in a short time.

3. Blocks of béton-coignet made on land are quite ready for immersion after drying and hardening for three or four days, while blocks of hydraulic concrete usually require from three to six months for drying and hardening.

To supply the daily demand for these blocks of concrete in the construction of a breakwater, large yards are necessary, which are usually at a distance from the breakwater. They must have space for 1,000 to 2,000 blocks in various stages of fabrication and drying; they require, also, a large establishment of machinery and railways; a large capital is thus invested and the expense is heavy.

In making béton-coignet less machinery and plant, less ground for drying, less preparation in advance are required, the time and capital involved are less, and the whole cost is consequently diminished.

Mr. Coignet now proposes the construction of piers and breakwaters in the following manner:

1. Blocks of béton to be made on land, in length equal to the breadth of the pier and of corresponding size, weighing say 140 tons, to be lowered into the sea, and placed side by side, across the line of the pier, for foundation.

2. The wall to be constructed likewise of béton, in

place, forming thus a single mass, binding the blocks below by the weight and solidity of the wall.

For this he would use from five to seven parts of sand, one of lime, fat or slightly hydraulic, and one-fourth to one-half part of cement.

But it is not probable that the government engineers consider the experience already gained sufficient to warrant them in recommending so great an outlay at present as this experiment involves.

The materials of béton-coignet exist in abundance in all countries and in most localities, seldom requiring long and expensive transportation.

Sand is easily excavated, lime is a simple preparation, and both are materials of low cost; most of the labor in making is performed by machinery, and little of the manual labor required need be skilled labor.

Sand, lime, water, machinery, motive force, few tools and common labor, are the elements of structures made of béton; and the béton itself is well adapted to numerous daily wants, in which solidity, durability and cheapness are preferable to beauty of materials, the evidence of which is shown in the ground and underground structures of the great palace of the Exposition, and in its increasing application to sewers, tanks, foundations, floors, walls, &c.

The cost of béton varies with that of the lime and cement employed. In Paris, works in béton cost, including fabrication and construction, from $5 to $8 per cubic yard. Flagging, two inches thick, costs 56 cents per square yard.

Ransome Artificial Stone.

"If Mr. Ransome has not found the philosopher's stone, he has at least produced a stone worthy a philosopher, and which promises to become the stone of the ages. For it appears to have elements of great durability, and it certainly possesses every other quality desirable in building stone, whether for structure or ornament. Although five years are not five centuries, chemistry has analyzed even the tooth of time, and can produce, within the period of a comparatively brief experiment, results identical with those of ages of atmospheric corrosion and disintegration. Mr. Ransome's stone has been boiled, and roasted, and frozen, and pickled in acids, and fumigated with foul gases, with no more effect than if it had been a boulder of granite or a chip of the blarney stone. It has been boiled and then immediately placed on ice, so as to freeze whatever water might have been absorbed, and it has been also roasted to redness, and then plunged in ice water, but without any sign of cracking or softening, superficially or otherwise. Nor does its durability rest alone upon such evidence as this, for it is of the simplest chemical composition; and chemistry and geology alike testify to the durability, if not the indestructibility, of a stone which is nearly all silica, like flint, and onyx, and agate, and jasper. It has no oxydizable constituent; for silica, or silicic acid, is already oxydized, and thus it is unalterable in air; and as the new stone is almost impermeable, it will suffer little, if any, injury from moisture or frost.

"And how marvellous, for its simplicity and beauty, is the process by which this stone is made! Some

toiling mason or other, hewing in the quarry or in the builder's yard, must have wished, before now, that stone, like iron, might be melted and run in moulds, even though his own occupation were thus at an end. Did he ever, when by the sea-shore or by a sand-pit, think of cementing indissolubly together the countless millions of grains into solid rock? Mr. Ransome, no mason, however—unless he be, as he may be for anything we know, a member of the mystic brotherhood—did think of this. And he tried every cement he could lay his hands to, and did not succeed. The sand became little else than mortar by such sticking as he could effect. But he found out, at last—and we are speaking of a time more than twenty years ago—that the best sandstones were held together by silicate of lime. And so he set himself to work to produce this substance, indirectly, from flints, of which plenty could be found for the purpose. But the flints had to be liquefied first, and how could this be done? Not by heat, nor would caustic soda touch them, so the chemist said. Flints might be boiled in a caustic solution for a week together, so long as the boiler was an open one, and lose very little by the operation. But by-and-by Frederick Ransome made one of the most unexpected discoveries in chemistry, viz., that when boiled in a caustic solution, *under pressure*, flints would melt almost like tallow before the fire. But we are not about to give the long history of the invention. With flint soup, or silicate of soda as a liquid, the question was what other liquid would, in mixing with it, turn both into an enduring solid? What other liquid would turn both into silicate of lime, the substance he was seeking? When he found

that chloride of calcium (in solution) would, when mixed with silicate of soda, turn both into flint, or something very much like it, the road was clear, and the manufacture of stone from sand was as simple and as beautiful a process as the making of Bessemer steel from pig-iron by blowing air through it when in the melted state.

"During the month of June, 1867, on the occasion of a visit of a party of about one hundred and eighty gentlemen, comprising heads of public offices and boards, chemists, geologists, engineers, architects and others, to the new works of the Patent Concrete Stone Company, at East Greenwich, Mr. Ransome showed and explained the whole process of making stone from sand, and exhibited some hundreds of the objects and ornaments, many of them of great beauty, already made to the order of architects and builders for various new buildings in England and abroad.

"The sand, a clean-grained, slightly brownish sort, just such as a dishonest grocer might select for increasing the gravity, specific or otherwise, of his sugar, comes from near Maidstone. There is no end to the quantity of it, and we believe it costs less than three shillings a ton in the Thames. There are flints enough for a hundred years to come brought up from the chalk pits at Charlton; and the caustic soda and the chloride of calcium, the latter a waste product of the soda manufacture, are bought of the wholesale chemists. The silicate of soda is made from the flints and caustic soda as follows: The flints are heaped upon iron gratings within a series of cylindrical digesters, of the material, size and form of small steam-boilers. A solution of caustic soda is then added; the digester

is then closed steam-tight, and the contents are boiled by steam of seventy pounds taken from a neighboring boiler and led through the solution in a coil of iron pipes. The solution of caustic soda is prepared of a specific gravity of about 1.200. The flints are dissolved into 'soluble glass,' and are drawn off in that state as a clear though imperfectly liquid substance, which is afterwards evaporated to a treacly consistency and color, and of a specific gravity of 1.700.

"The sand is completely dried, at the rate of two tons an hour, within a revolving cylinder, through which hot air is forced by a centrifugal fan. A small portion of finely ground carbonate of lime, say Kentish rag, or even chalk, is mixed with the sand, the more closely to fill the interstices; and each bushel of the mixture is then worked up in a loam mill along with a gallon of the silicate of soda. Thoroughly mixed with this substance, the sand has a sticky coherence, sufficient to enable it to be moulded to any form, and when well rammed, to retain its shape, if very carefully handled. In this condition—moulded, of course, and any thing that can be done in founder's loam may be done in this sand, sticky with silicate of soda—in this condition it is ready for the solution of chloride of calcium. The instant this is poured upon the moulded sand, induration commences. In a minute or so little lumps of sand, so slightly stuck together by the silicate of soda that they could hardly be kept from falling to pieces within the fingers, were solidified into pebbles so hard that they might be thrown against a wall without breaking, and only a short further saturation was necessary to indurate them throughout. In other words, on the instant of con-

tact, the silicate of soda and the chloride of calcium mutually decompose each other and reunite as silicate of lime and chloride of sodium, the former practically indestructible in air, the latter, common salt, perfectly deliquescent and removable by washing, although the stone, *after* the washing, is impermeable to water. Plaster of Paris does not set quicker than silicate of soda and chloride of calcium.

"The chloric solution is first ladled upon the moulded sand, and, the hardening going on, the objects are afterwards immersed in the solution itself, wherein large pieces are left for several hours, the solution being boiled in open tanks by steam led through it in pipes. This expels any air which may have lodged in the stone, and possibly heightens the energy of union with the silicate.

"After this the stone is placed, for a longer or shorter time, according to the size of the object, under a shower bath of cold water. This is not, by bathing, to convert it into Bath stone, although were the Bath stone a sandstone instead of an oolitic formation, this name would do as well as any. The salt, or chloride of sodium, deposited throughout the interstices, is sought out and washed away, in brine, by the water, and were it not that a portion of undecomposed chloride of calcium is also washed out, this brine might be profitably evaporated for common salt. Now, this searching out of the salt by the water would appear to prove that the stone was perfectly permeable, but, by one of those paradoxes with which chemistry abounds, the stone, when once freed from salt, is almost impermeable. The action is one which, if it can be explained at all, can only be explained as one

of the phenomena of dialysis, as experimentally investigated by Professor Graham. There is no doubt whatever that salt has been deposited everywhere throughout the stone, no doubt that it is afterwards completely washed out, and yet the stone as effectually resists the passage of water afterwards as if it were granite or marble.

"It is not necessary to describe the variety of objects that may be made in the new stone. It is practically a fictile manufacture, although not indurated by fire, and, unlike fictile goods, having no shrinkage or alteration of color in the making. Whatever the required size of the finished stone, it is moulded exactly to that size, with no allowance as in moulding fire-clay goods or in pattern making for castings in iron. The heaviest blocks for works of stability, and the most elaborately ornamental capitals, tracery or copies of statuary may be made with almost equal facility. For any purpose for which natural stone has ever been used for construction or architectural ornament, the artificial stone will fitly take its place. Mr. Fowler has used it extensively in the stations of the Metropolitan Railway; Messrs. Lucas Brothers have used it with success in various works; several manufacturers at Ipswich and elsewhere have the bed-stones of their steam engines, steam hammers, oil mills, &c., formed of the new stone. Mr. Ransome has moulded a large number of Ionic capitals for the New-Zealand post-office, and still more richly embellished capitals, modelled from those of the Erectheum at Athens, for public buildings at Calcutta, besides a great amount of decorative work for English architects. We understand that some thousands of Corinthian capitals of

this stone are specified for the new St. Thomas' Hospital.

"While, however, the new stone affords every facility for ornamental moulding, we consider that its more important purpose is as a substitute for ordinary cut building stone, and for that employed in pilasters, window dressings, garden balustrades, &c. It is truly the stone for the million, as well as for the mullion, and ought to take the place of stucco for exterior work in our town houses. We have not heard that the workmen have set their faces against it, although an intimation of this sort would not surprise us; but we should suppose that a proper knowledge of its advantages would insure its general adoption in spite of any possible opposition of this kind. We believe it to be the fact that builders are slow to move, but there are always exceptions, and, as in other trades, great improvements like this will make way against all opposition."

The extreme hardness of the silicious cement which binds together the grains which compose this material, secures it from the rapid disintegration which takes place when steel tools are ground on the best grindstones formed from natural rock. The following interesting notice of these stones is derived from the same source to which we are indebted for the foregoing description:

"The success which has attended the application of Mr. Ransome's beautiful process to the manufacture of artificial grindstones has been so marked, that there seems little doubt that the use of natural stones for grinding purposes will eventually become the excep-

tion instead of the rule. Amongst other firms, Messrs. Bryan, Donkin & Co., the well-known engineers of Bermondsey, have tried experiments which very decisively prove the advantages of the artificial over the natural stones. Messrs. Donkin were first supplied with a pair of Mr. Ransome's artificial grindstones in December last, and early in the present year they carefully tested these stones and compared their efficiency with some Newcastle stones at their works. Both the natural and artificial stones were mounted in pairs on Muir's plan—a system in which the peripheries of the two stones of each pair rub slightly against each other, with a view of causing them to maintain an even surface—and the two sets of stones were tried under precisely the same circumstances, except that the Newcastle stones had a surface speed more than twenty per cent. greater than that of the others.

"The trials were made as follows: A bar of steel, three-fourths of an inch in diameter, was placed in an iron tube containing a spiral spring, and the combination was then arranged so that the end of the bar projecting from the one end of the tube barely touched one of the artificial stones, while the other end of the tube rested against a black of wood fixed to the grindstone frame. A piece of wood of known thickness was then introduced between the end of the tube and the fixed block, and the spiral spring, being thus compressed, forced the piece of steel against the grindstone. The same bar of steel was afterwards applied in the same way, and under precisely the same pressure, to the Newcastle stone, and the time occupied in both cases in grinding away a certain weight of steel from the bar were accurately noted.

"The results were, that a quarter of an ounce of steel was ground from the bar by the artificial grindstone in *sixteen minutes*, while to remove the same quantity by the Newcastle stone occupied *eleven hours;* and this notwithstanding that the surface speed of the latter was, as we have stated, more than twenty per cent. greater. Taking the twenty per cent. greater speed of the Newcastle stone into account, it will be seen that the eleven hours run by it were equal to thirteen and three-quarter hours at the same speed as the artificial stone, and the proportional time occupied by the two stones were thus as sixteen minutes to thirteen and three-quarter hours, or as one to fifty-two, nearly!

"Such a result as this is something more than remarkable, and it is one which would scarcely have been credited, even by those who made the experiments, if it had not been fully corroborated by subsequent experience in the working of the artificial grindstones. Since the experiments above described were tried, Messrs. Donkin have set another pair of the artificial stones to work, and these, which are now in regular use, have given even more satisfaction than those first tried. The saving in time, and consequently in labor, effected by the use of the artificial grindstones, is, in fact, so great, that Messrs. Donkin have determined to use these stones exclusively in future; and we may add, that the artificial stones are so much preferred by the workmen, that those men, even, who are employed in shops at some distance from that in which the stones at present in use are situated, prefer taking the trouble to go to them to using the Newcastle stones in their own shops. In

addition to their great efficiency, the artificial grindstones possess the advantages of being able to be manufactured of any size, and of any degree of coarseness of grain, and they can thus be specially adapted to any particular class of work, while the process of their manufacture insures their being of uniform texture throughout, and free from the flaws and hard and soft places found in natural stones. Altogether, we believe that the general adoption of the artificial grindstones is merely a matter of time."

CONCLUDING REMARKS ON SOLUBLE GLASS.

It has been stated that Liebig and Kuhlmann recommend the substitution of infusorial earth to sand, which is a silicious stone, and is entirely composed of millions of the remains of organic beings, called diatoms, which are mostly unicellular plants, and have a silicious shell, and pass under the name of infusorial earth or tripoli, or mountain meal, and has generally been used for polishing stones and metals. This infusorial earth was first brought from Tripoli, but abounds in many localities in North Wales; in Bohemia, where are beds of fourteen feet in thickness; in Planitz, in Saxony, and in the United States, there are many places abounding in dried up lakes and rivers from the fresh water tertiary. In Virginia, near Richmond, there is a bed of thirty feet in thickness, belonging to the eocene period, and extending from Herring Bay, on the Chesapeake, Maryland, to Petersburg, Virginia. At Monterey, California, there is a bed of fifty feet in thickness; also in Barbadoes. These organic beings are extremely minute; the Bilin Tripoli is said to contain forty-one millions of individuals in every cubic inch, which weighs about 220 grains. The fresh water infusorial earth occurs bountifully in Connecticut, Massachusetts and New-Hampshire, where thousands of tons may be dug out.

Much time must have been required for the accumulation of strata in which countless generations of

these diatoms have contributed their remains, and these deposits have led to further discoveries, so that many materials which have been supposed to be inorganic, have been found to be composed chiefly of microscopic organic bodies. As a proof may serve—the white chalk—every minute grain of which abounds with thousands of well preserved organic bodies ; and the white coatings of the flints are often accompanied by innumerable needle-shaped speculæ of sponges.

Dust showers, which have been known to travel for long distances, have been known to consist of microscopic organisms, and almost invisible to the naked eye. The green sand of New-Jersey, which belongs to the later cretaceous group, and contains these innumerable organic remains, consists of 50 per cent. silica, 25 per cent. iron peroxide, 10 per cent. alkalies of potash and soda, 10 per cent. water, and a trace of phosphate of lime, belongs to the cretaceous formation, and has a thickness of 500 feet, and extends from Staten Island to the head of Delaware Bay, thence across to the Chesapeake and so on to the South. The rich guano deposits of South Carolina are included in this cretaceous period.

In order to make the New-Jersey green sand and the other infusorial deposits available for our purpose, the green grains have to be separated by a sieve from the accompanying marl; thus separated, they are treated with hydrochloric acid, and after that washed frequently with water and dried. These sands are boiled for a few hours with caustic lye of soda, so that 120 pounds of the clear sand, treated with a lye containing 75 pounds soda, must produce a concentrated liquid of 250 pounds, nearly 40° B.

It is well known that the affinity of silica for alkali is so feeble that it may be separated from this base by the weakest acids, even carbonic acid. In the silicification of stone, the carbonic acid of the atmosphere will set the silica free from the soluble glass, and the silica thus separated will be deposited within the pores and around the particles of stone or wood, so as to produce a perfect silicification, a protection or hardening of the stone, and prevention of decay from dry rot and from destruction by fire. The points of contact of these particles will thus be enlarged, and a coat of glazing of insoluble silica will be formed sufficient to protect those substances from the effects of moisture. Sandstones have, in this manner, been fully preserved. But whenever carbonate of lime or carbonate of magnesia enters ratably into the composition of building stone, then an additional chemical action, also sheltering the stone, is expected to take place between these carbonates and the soluble glass. An insoluble salt of lime may be produced, just as it is found in the native minerals, the dolomitic and oolitic building stones.

The principle of hardening cements, mortar and artificial stone, so as to render them impermeable to water and atmospheric agents, is based upon this expressed theory; this has been carried so far as to substitute the soluble glass, not alone rendering mortars water-proof, but also as a size in whitewashing and staining walls. The formation of an insoluble cement by means of the soluble glass, whenever the carbonic acid of the atmosphere acts on this substance, or whenever it is brought in contact with a lime-salt, has been demonstrated in the *Stereochromic Painting*, which is

equal to the process of *fresco* painting. It is the following process:

Clean and washed quartz sand is mixed with the smallest quantity of lime, so as to enable the plasterer to place it on the wall. The surface is then taken off with an iron scraper, in order to remove the layer formed in contact with the atmosphere; the wall is then still moist during this operation, but is never allowed to dry; after drying, it is just in the state in which it could be rubbed off by the finger; the wall is now moistened with the liquid soluble glass, which must be the compound of silicate of soda and potassa of the highest specific gravity, which operation is performed with a brush. It is after a little while in such a condition to be capable of receiving colors; if the wall has been too strongly fixed, the surface has to be removed with pumice, and to be fixed again. Repaired in this manner, the wall is suffered to dry. Before the painter begins, he moistens the part on which he proposes to work with soft water, which is squirted on by a syringe. As soon as the picture is finished, it is aspersed over with the soluble glass after the wall is dry, the syringing is continued as long as a wet sponge can remove any of the tint. An efflorescence of soda sometimes appears on the picture soon after its completion; this may be either removed by syringing with water, or may be left to the action of the atmosphere. Not to dwell on the obvious advantages possessed by the stereochrome over the real fresco, such as its admitting of being retouched, and its dispensing with joinings, it appears that damp and atmospheric influences, notoriously destructive of

real fresco, do not injure pictures executed by this process.

The decorations of historical pictures, the dimensions of which are 21 feet in height and 24¾ feet in width, single colossal figures, friezes, arabesques, &c., these pictures have all the brilliancy and vigor of oil paintings, while there is the absence of that dazzling confusion which new oil paintings are apt to present, unless they are viewed in one direction, which the spectator has to seek for. Leaves, or terra cotta, have been executed from a substance consisting in 75 parts clay and 25 parts soluble glass. The exudation during damp weather of the alkalies, either the potassa or soda, has always been a serious inconvenience ; by a careful washing with hydrofluoric acid, determine a complete insolubility. The silicious colors on glass have a certain semi-transparency, which is important to preserve, but which gradually diminishes by the action of water. Glass painted with silicates has been subjected to boiling in water without the colors being detached. These tints have even appeared brighter when seen by reflected light ; but if, after this apparent improvement, the effect is examined by transparency, the hues are found to have become duller, which is to be attributed to the capacity which they had acquired, resulting from the solution of a portion of silicious cement, which acts on these colors as oil does on paper. The careful employment of hydrofluoric acid gives a complete insolubility to paintings on glass, but chloride of ammonium slightly diminishes the transparency.

In an economical point of view, the soluble glass prepared from infusorial earths is much easier ob-

tained, and leaves less residue than that prepared from sand; moreover, the solution by alkalies may be made in a highly concentrated state in the first operation, so as to produce a neutral jelly, and suitable for the manufacture of soap and adhesive mucilage, while that prepared from sand can, at the first operation, only be brought as high as 25° B., and requires another tedious operation of concentration to the proper strength; and if the liquid is intended for certain purposes, the prevailing alkali requires a neutralization by hydrochloric acid.

We may safely bespeak for the abundant supply of infusorial earths a bright future in the manufacture of all-alkaline silicates.

THE ART OF GLASS MAKING.

Among all the discoveries relating to the arts, none exceed in importance and usefulness to mankind, the art of glass making. Glass is a chemical combination of sand and alkali, or alkaline earth, heated to fusion, and presenting after fusion a transparent and hard body. The benefits conferred by it upon all classes of human society have been immense; the spectacle, the microscope, the telescope, and spectroscope, have showered incalculable blessings upon the world, and there are probably still greater discoveries in store for us. The history of the manufacture of glass may be traced from the present time through that of the Romans and Phœnicians, to the Egyptians, some of whose productions remain to this age. The art flourished in Tyre, in Alexandria, and lastly in Rome; and after being depressed for some ages, again revived under the Venetians, who transmitted the improved art to the rest of the nations of Europe. Pliny relates that glass was first discovered by accident in Syria, at the mouth of the river Belus, by certain merchants driven thither by the fortune of the sea, and obliged to remain there and dress their victuals by making a fire in the ground. There being great abundance of the herb kali in that vicinity, the ashes of the plant, mixed and incorporated with the sand, formed glass.

Boerhave says, that the art of glass making is of ancient origin, being first cultivated in Egypt, while

glass was rendered malleable in the age of Tiberius, and is now manufactured in the greatest perfection. It is one of the most useful arts to mankind; for by it, in conjunction with the grinder's help, we obviate the natural infirmities of the eye. Without it, old people, and those whose optic nerves are affected, would be debarred the knowledge of reading letters or books, and would be unable to sit within doors, or in a coach or ship, and see all things clearly around them, yet without being exposed to the scourging heat or freezing cold, or being annoyed with the east wind, or the ingress of extraneous filth. Pure glass will scarcely receive any stain, and is easily cleansed again. Although the essential constituents of glass are silex and alkali, it generally contains other substances, such as metallic oxides, which are designed to modify its external character of hardness, fusibility, brilliancy, color and transparency. Many kinds of glass contain either potash or soda; the first is not much employed by the manufacturers of common glass. Some kinds contain lime and oxide of lead and alumina and oxide of iron; the two latter are, however, mere accidental impurities.

There are no reliable records of the processes employed by the ancients in the making of glass. From the time when Agricola, in 1550, described this art, the general arrangement of the furnaces, the mode of fabrication and the nature of the materials employed, and even the tools used in the glass-house, have undergone no material changes in the processes, if we may except a few natural substances, such as cryolite, fluorspar and felspar, all three of which have, for the

last two or three years, been introduced by glass makers, either for the opaque and vitrified glass, Reaumur's glass, or for assisting in the fluxing of the glass materials; also the substitution of bicarbonate of soda in place of soda ash. All works on the manufacture of glass are usually devoted to the arrangement and construction of the furnaces and pots, the tools employed by the workmen and the dexterous mechanical operations, by which the soft and ductile metal is shaped into various forms, that fit it for domestic use and the purposes of science and the arts.

The glass-house, in which the processes of melting and blowing are performed, is usually built in the form of a truncated cone, open at the top, 60 to 80 feet in height, and 40 to 50 feet in diameter at the base. In the centre of the area is situated the melting furnace, capable of holding from five to ten glass pots, or crucibles, for melting the materials. The grate of the furnace is nearly on a level with the floor of the glass-house; the ash-pit or cave is a subterranean passage, extending from each side of the furnace to the exterior of the building, so as to catch the wind from as many aspects as possible. The particular arrangement of the glass-house and the construction of the furnaces are somewhat varied according to the glass prepared.

The plan of a flint glass-house furnace is made to contain ten pots, with as many flues, one flue being placed between every two pots, and immediately abreast of each pot and between two flues is an aperture, called the working-hole, which is used for introducing the raw materials and taking out the glass or metal. The coals are shoveled through a square hole upon the grate in the centre of the furnace. The grate

bars are supported by two strong iron sleepers, and are protected from the intense heat by being previously covered by a layer of clinkers or potsherds; but as the furnace attains its maximum heat, sufficient clinkers are formed to serve the purpose. All around the grate room a bank is raised termed the ridge, on which the pots are placed, so that the fire lies, as it were, below the bottom of the pots and in the centre of the furnace. The sides of the furnace are a little higher than the top of the pots, and the arch or crown is made as low as possible to be consistent with durability. The ladle for taking out the metal and the stirring rod, all made of wrought iron, are the appendages of the pot. The following are the dimensions of a flint glass melting furnace:

A ten pot furnace is 12 feet 7 inches in interior diameter, (while each pot is 36 inches in diameter,) including the flues; the height to the inside of the dome is 4½ feet; each of the arches is 3 feet 1 inch by 3 feet 3½ inches, to the highest part. The fire is regulated by the stoker or tender, who can raise the heat of the furnace to the highest pitch by opening holes at the bottom of the grate. A ten pot furnace consumes from eighteen to twenty-four tons of coal per week.

The prevailing high temperature of a furnace, which is about 20,000° F., makes the construction of a melting furnace very difficult, in wear and tear; and in cases where open pots are employed, the difficulty is materially increased by the volatility of the alkalies, which amounts to nearly twenty-five per cent., both pots and furnace rods becoming worn out or too much corroded for use. In ordinary cases, three years is the usual duration of these furnaces, except in flint glass-

houses, where they last longer, from the lower melting point of the materials and the peculiar shape of the pots. The sides of the furnace are constructed of bricks formed in moulds made for that purpose. The best fire clay, mixed with the remains of old pots coarsely ground, is the material employed for making these pots. The roof is generally made of sandstone alone, of a coarse grit and very porous. No cement is employed in the arch; the expansion of the stone and the partial fusing of the interior surfaces afterwards, bind the whole sufficiently well together.

The crown and plate glass furnaces are similar to the flint; they are placed also in the middle of the cone, but contain only from four to six pots, each of the capacity of half a ton of metal.

In crown glass furnaces there are also the blowing furnaces, the bottoming hole and the flashing furnace, besides an aperture in the latter termed the *nose-hole.*

The leer or annealing oven is one of the most important appendages of every glass-house; it is a low arch, open at both ends, in which the manufactured goods are allowed to cool gradually.

The arch is usually about sixty feet in length, five feet wide and not more than from one to two feet in height. Adjoining the door or receiving end is a small furnace on each side, by which the temperature at that end is maintained just short of a melting heat; but as there is no other heating power, the arch or oven experiences less and less of the heat as the distance from the mouth is greater, until, at the remote or discharging extremity, the temperature is scarcely higher than that of the atmosphere.

There are, usually, from two to four of these an-

nealing arches placed side by side. Along the floors of each is a miniature railway, upon which two rows of iron trays, called *leer pans*, travel from the pot to the cooler end, where they are taken out. The pans are moved slowly along the leer by means of an endless chain, or sometimes they are gradually pushed forward by the trays last put in. The fuel employed is coke, which imparts the most regular heat for annealing, and is the freest from smoke, the carbon of which, when coal is used, injures the color of the glass. The time required for proper annealing varies from six to sixty hours, the weighty articles requiring the most heat and time. The hotter the goods enter the oven the better, and on this account large articles, before being introduced, receive a final reheating at the mouth of an empty pot, heated by beechwood, and called the *glory-hole.* Much of the success of the annealing depends on the proper direction of the wind, which ought to pass over the fuel of the leer towards the leer chimney at the cooler end, so that the hot air may always radiate in the downward current upon the goods. When an upward or contrary current of wind drives back the heated air from the cool or chimney end towards the fuel at the upper end, where it comes in contact with the hot articles just introduced, great losses from breakage often occur.

Kilns, which are closed at the further end, were formerly in general use for annealing goods intended for deep cutting, the kilns, when filled, being carefully closed up along with the burning fuel. The time required for cooling in this case was usually about a week; but to avoid so much delay, the kilns have been superseded by the use of iron covers, or a bed-

ding of sand in leers, and by lengthening the leer fire-places, and not filling the pans with glass too quickly.

The pots or crucibles in which the vitrious mixture is melted, require every care to be taken in their preparation. Those used for bottle, crown and plate glass, have the form of a truncated cone, the narrow end being the base. Their depth is usually four feet six inches, their diameter at top from four feet to four feet six inches, and at the bottom about three feet four or six inches. The pots for flint glass are hooded or covered at the top, and have a mouth like a muffle in front; but those for crown, plate and bottle glass are open. The horseshoe shaped piece of fire clay is inserted in the mouth during the melting, to diminish the aperture.

Fire clay is the material of which the glass pots are made, and it must be as pure and refractory as can be obtained, free from every trace of zinc in any state, and sulphide of iron, and the less oxide of iron the better. The kind of slate clay dug out of the coal formation near Stourbridge, which contains very little, if any thing, besides silicic acid and alumina, is decidedly preferred to all other compounds found anywhere. The clay is mixed with varying proportions of the remains of the old pots, and the *tempering* or previous preparation of the mixture, and requires great attention. A certain quantity of the ground materials, after being mixed with water, is stored away in large wooden bins or receptacles, and turned over from time to time, during which a workman treads it under his naked feet. This kneading of the clay renders it very uniform, and free from particles of air. The follow-

lowing is the composition of some of the clays employed:

Silicic Acid,....	68.05	63.70	64.10	63.99	61.79
Alumina,......	18.85	20.70	23.15	20.84	18.97
Lime,..........	.80	1.30	—	.30	1.53
Magnesia,......	—	.90	—	—	.91
Iron,..........	5.10	1.00	1.85	.75	.17
Water,........	6.10	10.30	10.00	11.67	14.79
Loss,..........	1.20	3.00	—	1.31	1.86

But the most suitable clay for glass pots of any description are thirteen parts of crude aluminous clay, twelve parts calcined silicious clay, and three parts of remains of old pots.

The addition of old pots assists in the more regular drying of the pots, and rendering the whole body more porous, and less liable to crack by heat. When the mass has been kneaded three times over, until it acquires a pasty mixture, it is rolled into small pieces about the size of a sausage, and then wet rolls are placed together upon a wooden or leaden slab, to the thickness of four inches, to form the bottom. It is then turned up at the edges, and built layer above layer in successive rings, all formed by the eye of the workman without the use of a mould. When the pot has been finished, the sides are made smooth by means of small wooden scrapers.

After the glass pot is formed, it is allowed to remain for a considerable time in an apartment heated by a flue to a little above the ordinary temperature, say 80° Fahr., in order that it may be slowly dried in an equal manner throughout its whole thickness. Two

or three years is the time allowed by some manufacturers for the gradual desiccation.

Before the pot is set in the furnace, it must be subjected to an annealing process, which consists in gradually increasing its temperature during several days to bright redness; this is usually done in a reverberatory constructed for the purpose, the fire in which must be raised very slowly, not more than a shovelful of coal being introduced at a time, and that at regular intervals. While at a bright red, or even white heat, the pot is quickly transferred, with the assistance of adequate machinery, into its seat in the hot furnace; a part of the face must be pulled down, to allow of the extraction of the old pot, and introduction of the new one. Before the pot is used it is *glazed*, as it is termed, before being filled with materials, that is, some cullet or old glass is thrown into it and spread over the sides in a molten state; this penetrates to the depth of a few lines into the substance of the pot, and forms a hard difficulty—fusible enamel—which protects the pot from further action of the substances added.

The setting of a pot is a very arduous undertaking, and some dangers attend it, on account of the dense heat to which the workmen are exposed; it is generally done by the glass-house crew, and is done at the end of the week, when the work of the glass-house is slackened. As a test of the soundness of the pot, throw a small lump of coal against its side; if, when struck, it rings well, its future is promising; but if it returns a dull sound, it will probably be short-lived in the furnace. The average duration of the pots when thus fixed is about seven weeks; some attain

the age of ten or twelve, while others may terminate their existence prematurely, either from defective construction, or from bad treatment, such as if exposed to a cold air in the furnace, etc. etc.

The Crude Materials for Glass Making.

For the purpose of manufacturing the best quality of glass, the materials composing it ought to be perfectly pure; but it is quite impossible to obtain on a large scale or prepare the ingredients in a state of chemical purity. It is well known that true glasses are practically composed of silica or silicic acid, in combination with at least two alkaline bases or earths, and sometimes oxide of lead, zinc and other metals.

Silex is the principal ingredient, and is very abundant in nature, forming a principal constituent in rocks and stones, and existing in a free and almost pure state in flint, agate, chalcedony, rock crystal and quartz; the two latter are in the purest form. Flint glass obtained its name originally on account of flint being formerly used for the manufacture of glass; but *sand* is now employed as the most general and economical source of silica, rendering the process of grinding unnecessary.

At the same time, the great variations in the purity of this material render requisite a careful selection for the different kinds of glass, and the manufacturer must choose such as the microscope and analysis show to be most suitable for his purpose. The English sands of fixed quality are brought from Alum Bay, on the Isle of Wight, or Lynn, on the coast of Norfolk. The French obtain a very superior sand

from the forest of Fontainbleau, near Paris; in this country the best sand is procured from Berkshire County, in Massachusetts, and from several sand banks on the Mississippi River; but by far the largest quantity is brought from Maurice River, in New-Jersey, and also from the Florida coast.

The sand being always more or less impure when brought to the glass-works, is conveyed to an upper room and thrown into a trough of water, where it is carefully washed; it is then placed in a trough over an oven, and when partially dried passes through holes into the oven; when quite dry, it leaves the oven in the state of fine glittering white particles, like powdered quartz; this preparation is not required for green and bottle glass, only for the finer qualities. The alkalies, potassa and soda, are now employed in their purified state, although formerly crude potashes from wood ashes, and crude soda from Barilla, produced from the incineration of kelp, have always been used until the last thirty years, and which produced very variable and often most inferior quality of glass.

Le Blanc's discovery in 1792 of the conversion of common salt into carbonate of soda, effected a revolution in glass making. The general introduction of the carbonate of soda in England dates since 1831.

It is, however, noticeable, that sulphate of soda has for a long while been used in glass making, and rock salt is still in vogue in that country; the Newcastle black bottles are to this day made from common rock salt and the sand from the bed of the river, with the carbonate of lime of the soap works, and the tank waste of the alkali makers. The better classes of

glass are now manufactured from the purified sand and alkalies.

Lime forms an important constituent in flint glass; is used either as carbonate, slaked or burnt; but such lime which contains protocarbonate of iron is excluded from the mixture for white glass. The action of lime is to render the alkaline silicates insoluble, and when rightly balanced by the other ingredients, it promotes the fusion of the whole and improves the quality, but when added in excess, the glass becomes hard and difficult to work, and subject to devitrification.

Lead is the next substance in point of importance, forming the distinguishing ingredient in crystal or common flint glass, optical glass and strass. These glasses are fused from either litharge or red lead, the latter being preferred for several reasons; it is finer in a state of division—an impalpable powder; and because it is decomposed in the glass pot into ordinary protoxide of lead and oxygen, which latter assists in the oxydation and removal of many impurities, such as charcoal, &c. An excess of lead acts injuriously upon the melting vessels, and besides inducing too great softness in the glass, gives it a yellow tinge. There is, however, no danger of an excess of red lead being used by our glass makers, who have an eye to economy, brought about by the great competition of the glass makers in the various sections of the United States.

Baryta, as a sulphate or heavy spar, is sometimes added to the constituents of common bottle glass, to render it more easy of fusion.

Alumina, which is always an undesirable ingredi-

ent, and is seldom purposely introduced into glass, but is always accidentally present from the action of the materials upon the clay of the pots ; it renders the glass more liable to devitrification, for it increases the number of silicates and more compounded, which, as it is known, makes any glass, such as bottle glass, easily devitrified.

Iron is an unwelcome element in glass, but is always present in the sand, also in the sulphate of soda, in the chalk, partly in the state of protoxide, which, however, is removed by chemicals.

Arsenic.—A little arsenic promotes the decomposition of the other ingredients, and tends to dissipate carbonaceous impurities not otherwise disposed of, but in excess it produces a milkiness in the glass, which increases in tensity with the time.

Borax and Boracic Acid, as also the borate of lime, called hayesine, from Peru, are, like the Chili saltpetre, very useful and powerful agents for accelerating the fusing of the materials.

Fluorspar is now much in use, and were it not that fluorspar acts too detrimental upon the pots, and causing the metal to run through them, it would be the best material and the most economical in glass making.

Felspar gives a good body to glass, and this, with bone ashes and silex, makes a milky glass.

Bone Ashes are likewise much employed for producing a white opalescent glass.

Green Sand, from the cretaceous formation, containing the infusorial deposits of silicious shells, called diatoms, may be substituted for sand or silex in some glass varieties.

Cullet, a quantity of waste glass, which is abundantly produced in every manufactory of glass, and which is more fusible than the raw materials, facilitates the melting. The cullet from the glass-house, and that collected in the neighborhood, are carefully sorted, cleaned, ground and incorporated with the mixture for similar kinds of glass. Care must, however, be taken that no inferior kind of cullet is also mixed with the ingredients for finer glass. Cullet set alone excites fusion, but materially aids the union of the bases with the silicic acid.

Decoloring Materials.—Every description of glass has a tendency to color, which is more or less developed, even when proper proportions and the purest materials for the mixture have been employed; and as any tinge is considered a defect in white glass, or that which is employed for windows, and particularly in the finer kinds of glass, certain materials are employed with the special object of counteracting it. To this class of substances belong peroxide of manganese, arsenic and nitrate of potassa. The accidental elements which usually color the glass are iron and carbon, or carbonaceous matter, and in all cases the substances just mentioned are employed to neutralize or counteract them by means of oxydation.

If particles of carbon, as soot, from the flame or fire, become mixed and surrounded with the melted glass, these, by their exclusion from the access of air, are prevented from burning, and a brown or nearly black color is produced, which is removed by the conversion of the carbon into carbonic oxide through the influence of the oxydizing or decoloring material. The manner in which manganese acts on the protoxide of

iron is similar to its action on carbonaceous matters, which are thus removed in gaseous form from the melted mass. A few ounces of the peroxide of manganese are, therefore, usually added to the materials for making flint glass, which is always required in a state of great purity, and from the cleansing action of this material, it has received the familiar title of *glass-makers' soap.* It must, however, be used sparingly, for an excess of it produces a compound of silicic acid with sesquioxide of manganese, which communicates a lilac or amethystine color to the glass. The approved remedy for this, when the error has been committed, is to stir up the colored mass with a wooden pole, which reduces the sesquioxide to the protoxide, and the lilac color disappears. Some manufacturers use manganese on account of the reddish tinge it imparts to glass, expressly to disguise the bad green or yellow colors produced by the other materials. In this case two tinged glasses are formed, which mark each other's defects, the green and red rays combining together as supplementary colors to transmit white light. In fact, in plate glass for fine windows a slight excess of manganese is sometimes allowed, expressly to produce an amethystine tint, which improves the complexion of persons who receive the light of day through the window.

Smalt, a blue glass, is sometimes used like manganese, to mark the bad colors produced by the other materials. Properly speaking, however, decoloring agents are those which act by oxydizing the carbon or the protoxide of iron, and thereby actually expelling the lime. In this way nitrate of potassa reacts before the glass enters into perfect fusion; arsenious acid,

arsenic acid and their salts exert their action at a temperature above the fusing point, and are volatilized.

Felspar has been recommended many years ago, on account of its ready vitrification, as a good material for window glass, and the following mixture was said to be proper, viz.:

2	parts of	felspar,
2	"	sand,
1	"	chalk,

which, however, was difficult to melt and prone to devitrify.

Another mixture has been proposed, to consist of

100	parts	felspar,
100	"	clay,
80	"	quicklime,

which mixture produces a bottle glass, provided the clay is free from iron. At the present day felspar is used in connection with sand and fluorspar, and lime and bone ashes are added by some manufacturers for producing a milk-white, semi-transparent enamel glass.

Glass from Volcanic Products.—Certain lavas, pumices, pitchstone, obsidian and similar products, approach so closely to bottle glass in their composition, that there is no doubt but what they will be turned to account.

Of pumice stone, forge scoriæ, chalk and a little soda, in proper proportions, bottle glass must be made. Basalt would require the addition of chalk and soda. Lava has been melted without the addition of other ingredients, and produced a fair bottle glass.

The Fuel.—In England, coal was formerly employed exclusively in the manufacture of glass, but it has been found of late that *oven-burnt coke* is much

better adapted for the finer glasses, as it produces less smoke and soot. Some glass-houses have all the requisite accommodations for making coke. In France, both coal and coke are used, as also wood; the latter produces, however, less heat than coal, and it would require a longer time to fuse the metal. In Germany, wood, and also peat, is generally employed, and it may be safely recommended to our American glass manufacturers to employ peat in their furnaces for obvious advantages; it makes no smoke, gives less ash, burns with a bright flame, gives much heat, and is economical, and can be had in the United States in large supplies.

Preparation of the Materials.—A great saving of time and fuel is effected by carefully grinding and intimately mixing the materials previous to the melting; for this purpose edge-stones and coarse sieves are essential in a glass-house. The mixing and sifting has hitherto been performed with the hand, and very imperfectly. A mixing apparatus, especially intended for crown glass, has been contrived; it is made entirely of wood, and consists of a semi-cylindrical chamber, with an opening at the top for introducing the materials, and another in the semi-circular bottom, through which they are removed, a cylinder in which a number of oblique beaters are fixed, and the whole made to revolve by a handle or a shaft of a steam-engine. Also, a simple revolving wooden board, similar to those employed in the powder factories, answers all its purposes.

The composition when mixed is termed *frit;* the great advantage of fritting or stirring the materials together is in the partial union which it effected be-

tween the silicic acid and the bases, so that the latter were not volatilized in the furnace previous to the formation of the glass, and the pots and sides of the furnace were consequently less exposed to the injurious action of these vapors.

Melting.—The raw materials, consisting essentially of sand and silica as the base and alkali as the flux or solvent, having been thoroughly incorporated with a suitable proportion of cullet or broken glass of the same kind, are introduced by means of a clean iron shovel into the melting pot, which has been previously raised to white heat. But the whole of the mixture is not introduced at once, for the mass of glass which a pot will hold occupies before fusion in the state of frit just twice the space of the melted glass; not more than one-third of the mixture is put in first; the temperature is then raised to the maximum, and as the mass subsides by the melting, a fresh quantity is introduced, until the pot is filled with melted glass. During the whole period of the melting or found, the stokers or teazers keep the furnace well supplied with fuel, so as to prevent any portion of the grates becoming uncovered, in which case a rush of cold air from below might split some of the pots. In order to notice the progress of the fusion, proofs or drops are from time to time taken out of the pots by means of a short rod, flattened at one end, and examining if any undissolved grains of sand are perceptible on refrigeration, and whether the mass appears uniform throughout; for as long as carbonic acid is evolved in abundance, or during the boil, the mass is agitated by the escape of large bubbles of gas, which is most favorable to the operation.

This action answers the purpose of stirring; it mixes the compounds of variable degrees of fusibility and density, which are first produced, with each other. At the close of the melting process, the contents of the pot are not by any means pure or equally mixed. All the solid matter is dissolved, but the mass of glass is full of small vesicles of gas, presents a spongy rather than a dense appearance, and is not yet in a fit state for working. The surface is also covered by a layer of so-called *glass gall* or *sandiver*, a melted mixture of salts, which have not been volatilized, nor combined with silica during the process of melting, and consisting chiefly of chloride of potassium or sodium, and sulphates, which, in consequence of imperfect vitrification, have escaped decomposition. Whenever glass gall occurs in large quantities, it is removed with ladles, and is mostly employed in chemical manufactories of saltpetre and alum; it does not occur when the purified materials have been employed; and if any glass gall rises, it may then be removed by volatilization.

Fining.—For some time the glass does not become transparent, the opacity being due to bubbles of air or gas, and to the lime and earthy impurities, which do not fuse. The object of fining, which is the last process in glass making, properly so called, is the removal of these by the subsidence of the heavier particles to the bottom and the escape of gas at the surface. For this purpose the glass must be brought to the most fluid state possible, and the heat is therefore raised and sustained for some hours at the highest point. In 40 to 48 hours after charging the vitrification is complete. When all the gas bubbles

have passed off, and the sandiver has become transparent and colorless, the temperature of the pot is lowered by diminishing the draught, which is termed *cold covering*, while the first heating process, just mentioned, is called hot covering.

The object is now to bring the glass from a state of nearly perfect fluidity, in which it could not be worked, to that free viscid or plastic condition necessary for the working. For this purpose the bars of the furnace are plastered up. The great thickness of the walls and the slow combustion of the fuel, which is supplied in moderate quantities, keep the furnace hot enough to retain the glass in a workable viscid state during the period in which the glass is blown or otherwise shaped into the required forms.

Faults in the Glass.—Notwithstanding all the precautions that may be taken, air bubbles frequently remain and generally exist in great numbers, when the fining process has been obstructed by too great difficulty of fusion in the glass; these are called *blisters*, *blibe* or *seed.*

There are some other accidents to which the glass is liable, such as the *threads* or strings, which are contracted during the blowing, and *waves* and *striæ* arising from a want of homogeneity in the vitrous mass; the latter is produced when the density of the glass, in consequence of imperfect fusion, is not uniform throughout, and all the parts, though equal in transparency, do not refract the light equally, and consequently images of objects seen through the glass appear out of place or distorted. This fault is very objectionable in plate glass for mirrors or windows, as well as in crystal or flint glass for optical purposes.

Waves are superficial and protuberant striæ, which always occur when the glass is blown too cold.

The working tools in the glass-house are to this day the same as have been described by Blancourt in 1699, without any variation; such as the tube, which is the most indispensable instrument, made of wrought iron, from four to five feet long, one inch thick, and about one-quarter inch in the bore.

It is provided with a bulb on each end; one serves as a mouth-piece, while the other is used to attach the melted glass on it; the upper portion is surrounded with a wooden cover, to protect the hands of the workman from the heat of the metal. Another solid rod, called the *pontil* or *ponty*, serves to receive the glass after it is blown on this pipe. The *springtool* is a species of tongs for laying hold of half-formed handles, and for seizing the glass while making. The *pucellas* are prongs resembling the cutting part of shears, but blunt, and are used for rubbing the outside of solid or hollow glass, and pressing it into a smaller diameter, at the same time elongating the parts by rotation. The *battledor* is made of wood, and is used for flattening the glass when necessary. The *shears* are strong scissors for cutting and shaping the edges and handles of glass vessels while in a soft state. The *fork* is employed for carrying the finished articles to the annealing oven. The *marver* is an iron plate or slab resting on stone or wooden supports, and having a polished surface, on which the mass of glass which has been gathered at the end of the blowing tube is rolled to give it a symmetrical form; marver is derived from the French word *marbre*—marble.

The glass-maker's chair is the last utensil used in the

glass-house; it is a flat seat of wood, about ten inches wide, each end of which is fixed to a frame connected with four legs and two inclined arms, upon which is screwed an edging of wrought iron for rolling the blowing tube with the hot glass backwards and forwards with the left hand, while the required form is given to the glass with the pucellas held in the right.

Continual rotation of the melted mass is the principal point to be attended to in most of the glass-blower's operations, but these may have to be explained when alluding to the various kinds of glass.

The manufacture of glass is divided into several classes:

A. Window glass, which includes,

1. Crown glass.
2. Sheet glass.
3. Brown plate, silvered or unsilvered.
4. Colored sheet, pot metal or flashed.

B. Painted and other kinds of ornamental window glass.

C. Cast plate glass.

a. Rough plate.
b. Pressed plate.
c. Rolled plate.

D. Bottle glass.

1. Ordinary bottle glass.
2. Moulded bottle glass.
3. Medicinal bottles.
4. Tubing.

E. Glass for chemical and philosophical purposes, retorts, reservoirs, large water pipes, etc., etc.

F. Flint or crystal glass, with or without lead; white, colored, ornamented, for table ware, etc.

1. Blown.
2. Moulded and pressed.
3. Cut and engraved.
4. Reticulated and spun with a variety of colors, incrusted, flashed, enameled of all colors, opalescent, imitation of alabaster, gilt, gelatinized, silvered.
5. Glass mosaic, miliflori, aventurine and Venetian glass weights.
6. Beads, and imitation of pearls, etc.
7. Chandeliers, candlesticks and lamp apparatus.

G. Optical glass, flint and crown.

1. Rough disks of flint and crown, to make lenses for telescopes, microscopes, stereoscopes, spectroscopes, daguerreotype and calotype apparatus.
2. Flint and crown, blown, or cast in plates for the optician.
3. Fine glass for microscopes.
4. Refractive apparatus, prismatic lenses for light-houses.

The above classification was made at the London universal exhibition of 1851. Another classification is made in the following kinds, according to their constituent materials:

1. The soluble glass, silicate of soda or potash, or both alkalies combined with silica.
2. Bohemian glass, a silicate of potash and lime.
3. Crown, or spread, a silicate of soda and lime.
4. Plate, a silicate of soda and lime cast into plates.
5. Bottle, a silicate of potassa, lime, alumina and oxide of iron.
6. Crystal, silicate of potash and oxide of lead.

7. Flint contains more lead than the last.

8. Strass, or paste, contains still more lead than flint.

9. Enameled and colored glass, from all the above except No. 1 and No. 5.

The following is, with some modifications, arranged by Knapp, beginning with the coarser or common qualities, and rising by a natural gradation to the finer or rarer kinds of glass:

I. Ordinary, or green bottle glass.

II. White bottle glass, including refractory Bohemian and pressed crown glass.

III. Window glass, or English crown, of sheet or cylinder glass.

IV. Plate glass.

V. Crystal, or common flint glass, and optical flint glass.

VI. Strass, and colored or stained glass.

VII. Soluble glass.

I. *Green Bottle Glass.*—The materials for common glass bottles are coarser and cheaper than for any other kinds of glass, and in consequence of this very coarseness or want of refining, the elements which enter into its composition are more numerous, consisting, as stated, of silica, lime, potassa or soda, oxides of iron and manganese; these last communicate a color to the glass, which owes at the same time its characteristic hue to the charcoal. Indeed, as the color of bottle glass may be considered as essential to it, or at least does not injure its sale or diminish its value for the

purposes to which it is applied, no recoloring materials are used, and it is melted in open pots, even when coal is used as fuel. The omission of decoloring materials forms the distinguishing feature of ordinary bottle glass.

The primary materials of the manufacture of this kind of glass are yellow or ferruginous sands, residues from the lyes of the soap and soda works, lixiviated ashes, common ashes and clay. The colored sands are preferable to white sand for bottle glass, the oxide of iron, which colors them, performing a part of a flux; they do not require any washing or other preparation; nevertheless, any coarse foreign substances, such as pyrites, flints, &c., are separated from them; for this purpose, they are dried and passed through a sieve. The clay best adapted for this purpose is a yellow marly earth, a furnace clay containing alumina, silica, carbonate of lime, oxides of iron and manganese; it has not much of a binding quality, and is easily reduced to powder when dry, which facilitates the mixture. The ashes are generally obtained from common domestic fires, and are sifted and dried before using.

The following formula is used in France for ordinary French bottle glass:

Varix, (kelp,)	30 to 40 lbs.;	sand, 100 lbs.
Lixiviated ashes,	160 to 170 "	
Fresh ashes,	30 to 40 "	
Clay, containing iron,	80 to 100 "	
Broken glass,	100 lbs.	

The English bottle glass is composed of—

Lixiviated ashes,	100 lbs.;	sand, 100 lbs.
Kelp,	40 to 80	"
Wood ashes,	30 to 40	"
Clay,	80 to 100	"
Cullet,	100 lbs.	

The amount of cullet is not particular; it is increased for the first and second melting when new pots are used; if a very argillaceous sand is used, it is necessary to suppress the clay, and supply lime by a suitable addition of chalk. Crude soda may be used.

Champagne and soda-water bottles:

For 100 lbs. sand, add	
Felspar,	200 lbs.
Lime,	20 "
Common salt,	15 "
Iron slag,	105 "

For ordinary green bottle glass:

Sand,	100 lbs.
Lime,	72 "
Lixiviated wood ashes,	200 "

Dark green bottle glass:

Sand,	100 lbs.
Dry glauber salt,	20 "
Soapboilers' flux,	18 "
Lixiviated ashes,	1 "
Glass from the hearth,	32 "
Broken glass,	179 "
Basalt,	45 "

Hock wine bottles:

Sand,	100 lbs.
Clay,	100 "
Sulphate of soda,	50 "
Best black lead,	25 "

The colored aerated water bottles:

To 100 lbs. of common sand, add

Sulphate of soda,	50 lbs.
Lime,	20 "
Felspar,	50 "
Zaffre,	5 "

The cheapest bottle glass is composed of—

Sand,	200 lbs.
Lime or chalk,	100 "
Common salt,	25 "
Iron slag,	50 "

The melting furnace for bottle glass contains commonly only six pots, about three feet in height and nearly the same in diameter; they are filled to the edges, and when the matter has sunk down and is converted into glass, more of the composition is put into the pots, and the fire is urged; the meltings are rapid, for as most of the bottle glass compositions furnish but little glass gall, no time is lost in firing. The process lasts from seven to eight hours, and when it is concluded the fire is slackened, that the glass may thicken to the point suitable for working it. For this purpose the fire-place is heaped up with small coal; draughts are intercepted as much as possible, and care

is taken not to touch the fire during the working of the glass, lest the combustion should be re-excited.

The working or shaping of bottle glass is very simple in principle, and yet the operations involved are somewhat complex in detail. The assistant collects or gathers at the end of the pipe the requisite body of glass, and passes it into the blower; the latter, by blowing and constantly turning the pipe, gradually forms the body of the bottle, which is finished in a mould. While the bottle is in the mould, the workman continues to blow and to turn; he then raises the pipe, and holding the bottle in a vertical and reversed position, he depresses or hollows the bottom; the bottle is then cut at the neck, and the iron rod, the ponty, fixed at the opposite end of it; the edge of the neck is rounded, and the ring or cord which encircles it is put on; the ponty then passes into the hands of the assistant, whose duty it is to carry it to the annealing furnace, and he then detaches it from the rod by a slight blow. Large round bottles are blown without the use of a mould, and when of very great size, like the carboys for oil of vitriol, the aid of steam is called in, by spirting about an ounce of water into the interior of the tube, and holding the mouth of the pipe with the thumb.

Bottles in the shape of flattened globes are also made without any mould by simple blowing. The preparation of the mass of glass, the formation of the concave bottom and of the neck is effected with ease by an expert workman; the swinging motion must not be continued for any length of time. In blowing the belly of the bottle, the workman stands in front of a slanting board, and presses the globe as it is

gradually formed by slow blowing against the board at every half revolution of the pipe ; the flat surfaces on opposite sides are thus produced.

Bottles intended to resist a high pressure, like champagne and soda-water bottles, have to be carefully handled, for, owing to internal pressure, may easily crack them, and occasion great loss and be even disastrous.

It has been ascertained that such bottles will stand a pressure of twelve atmospheres ; and various machines have been invented to affect the test by forcibly pumping water into the bottles until the manometer is of the sufficient degree of force used in this operation.

The mode of filling and annealing, as well as the form of the bottles, must exercise a great influence, which it would be necessary to find the means of estimating.

II. *White Bottle or Chemical Glass.*—Bottles for medicinal and chemical use, and tubing of a refractory condition. This is composed of purer materials than the green decoloring matters, and the materials as much free from iron and alumina as possible, and the glass is subjected to a thorough fining process.

Apothecaries' Phials:

White sand,	100 lbs.
Impure potassa,	30–35 "
Lime,	17 "
Ashes,	110–120 "
Manganese,	5 "
Cullet,	25 "

Bohemian Crystal, for grinding:

Sand,	100 lbs.
Purified potassa,	60 "
Chalk,	8 "
Broken glass,	40 "
Manganese,	1 "

Semi-White:

Sand,	100 lbs.
Crude soda, containing lime,	100 "
Cullet,	100 "
Manganese,	1 "

Clear White:

White sand,	100 lbs.
Calcined potassa,	65 "
Slaked lime,	6 "
White cullet,	100 "
Manganese,	5 "

White Glass, for chemical purposes:

Sand,	100 lbs.
Potassa,	41 "
Lime,	17 "

Bohemian Glass.—This glass is particularly valued for its refractory nature, freedom of color and great lightness; tubing, retorts, &c., will not alone resist high heat, but also sudden changes of temperature; also for table ware, costly windows for houses and carriages, for covering engravings, and in general for all those uses which require the glass to have a considerable thickness without coloration.

In common with crown glass, it is also peculiarly fit for optical instruments, in which it is employed to achromatize the flint glass.

It is made by the following formula:

Quartz in powder, or fine silicious sand, coated with hydrochloric acid,	100	110	120
Purified carbonate of potassa,	60	64	66
Pure carbonate of lime,	20	24	25

By analysis of the old manufactured Bohemian glass, was found

Silica,	69.4
Alumina,	9.6
Lime,	9.2
Potassa,	11.8

Bohemian glass is a silicate of potassa and lime, with a small proportion of alumina, magnesia and other ingredients.

Crown Glass.—It is likewise a silicate of potassa and lime, and the English crown glass contains the soda instead of the potassa.

The analysis of a German crown glass produced

Silica,	62.8
Alumina, ox. iron and manga ,	2.6
Lime,	12.5
Potassa,	22.1

The beauty and value of this glass depends upon its absolute limpidness, and requires the most careful selection of materials for the mixture and the pots,

and protracted and assiduous process of fining are required. Soda does not produce as colorless a glass as potassa, nor ought it to contain any oxide of lead, but requires lime; there is danger of devitrification if potassa is employed, and very good reasons are known to exist why lime in combination with potassa ought to be used.

III. *Window Glass.*—The glass, which has long been in common use for window panes, is that which is generally known as English crown glass, in the manufacture of which a large globe is first blown at the end of the pipe, and is converted by a rapid rotary motion into a circular plate or disc, thickened at the centre. Still better, the present method is to form a globe into a cylinder, and then, after cutting it up in a direction parallel to the axis, flattening it out into a broad sheet; from this fact it has been named "sheet glass." Plate glass, or that which is cast into sheets by pouring the liquid metal on a flat surface, is now much used for the same purpose, as for windows of shops, &c. The chief demand for plate glass is still for mirrors. The English crown and sheet glass are composed of precisely the same materials, and differ only in the mechanical operations by which they are brought into form. The composition of the English crown and sheet glass, under the name of window glass, are chiefly silica, soda and lime; sometimes potassa is added to the mixture. Alumina, oxides of iron and manganese are also found in window glass, either by accident or purposely; for where iron is present it requires the addition of manganese to neutralize the effects of iron; a little arsenic is also generally added to promote the decomposition of the other

ingredients. It is, however, a well ascertained fact, that no two manufacturers use the same materials, and it may even sometimes be necessary to vary the proportions of the composition, on account of the melting power of the furnace.

The following is the usual composition of the crown glass, viz.:

Sand,	500 and 548 lbs.
Chalk,	154 and 146 "
Carbonate of soda,	119 and 118 "
Sulphate "	63 and 17 "
Arsenic,	2 and 2 "
Cullet,	448 and 448 "

The French crown glass consists in—

Sand,	100 lbs.
Chalk,	35 to 40 lbs.
Dry carbonate soda,	28 to 35 "
Broken glass,	60 to 180 "
Peroxide manganese,	25 to 35 "
Arsenic,	20 to 30 "

The three following formulæ for crown glass:

White sand,	100 lbs.	100 lbs.	100 lbs.
Good potassa,	65 "	0 "	0 "
Good soda,	10 "	90 "	80 "
Lime, slaked,	6 "	0 "	8 "
Broken glass,	50 "	100 "	110 "
Arsenic,	1 "	0 "	0 "
Oxide of manganese,	$\frac{1}{3}$ "	$\frac{1}{3}$ "	$\frac{1}{3}$ "
Carbonate of lime,	0 "	5 "	0 "
Oxide of cobalt,	0 "	0 "	$\frac{1}{3}$ "

A beautiful window glass is obtained by the following formula:

Sand,	100 lbs.	100 lbs.
Dry sulphate of soda,	44 "	58 to 75 lbs.
Charcoal in powder,	4 "	4.5 to 5.5 "
Slaked lime,	6 "	13 to 15 "
Broken glass,	100 "	100 lbs.

The manipulations of the English crown glass is the following:

The metal or melted glass having been brought by the gradual cooling of the furnace from a state of complete fluidity to a consistence capable of being worked, the gatherer dips the end of his pipe or hollow rod of iron into the pot inside of a ring, which is kept in the furnace floating over the melting mass, and twirling it around its axis to equalize the thickness of the gathering, collects upon the end, or nose, as it is technically called, a pear-shaped lump of glass. Resting his pipe upon a stand or horse, he turns it gently around and allows the surface of the lump to cool, to be fit for a second gathering. So much glass is collected in this way in successive layers as will form a disc or table of about nine pounds weight, which an experienced workman can easily guess; the lump completed, the gatherer having cooled his pipe under a trough of water, that he may handle it at any point, proceeds to roll the glass upon a marver until it assumes a conical form, the apex of the cone forming what is termed a bullion-point. A boy now blows down the pipe while it is still being turned by the gatherer on the marver, and expands the glass into a small

globe. Having been heated, it is blown again, and assumes the shape of a florence flask, and the future rim of the developed plate or disc is prepared by rolling the *piece*, as the glass under operation is termed, near the pipe nose upon the edge of the marver. Again heated, it is now expanded by the blower into a large globe; again presented to the fire, by the peculiar manipulations of the workman and the peculiar direction of the flame upon it, the front of the globe is flattened, the possibility of the globe collapsing during this operation being prevented by its rapid revolution around its axis. The piece now resembles somewhat in shape an enormous decanter, with a very flat bottom and a very short neck. The pipe is laid horizontally upon an iron rest, and a man approaches, having in his hand the large rod, the ponty, tipped with a lump of molten glass; pressing this lump upon an iron point so as to give it the form of a little cup, he fits it, when thus shaped, on to the bullion-point, to which it soon becomes firmly attached; the lump thus formed is called the bull's-eye or bullion of the developed plate. The incision of a piece of cold iron in the glass around the nose of the pipe, and a smart blow, soon detaches the pipe, leaving a corresponding hole in the flattened sphere at a point exactly opposite the attachment of the ponty; the blowing pipe thus removed, and carrying with it a piece of glass, is allowed to lie idle a few minutes, till the glass adhering to it has cracked off; it is then warmed and carried back to the pot to repeat its course in a similar operation. The open projecting end of the piece which was next the now detached pipe, is called the nose, and gives its name to the furnace or nose-hole.

It is now the glass undergoes its last operation. A man stands in front of a huge circle of flame, termed the flashing flame, into which he thrusts his piece rapidly, meanwhile revolving his ponty. The action of heat and centrifugal force combined is soon visible. The nose of the piece or hole caused by the removal of the blowing pipe enlarges, the parts around cannot resist the tendency, the opening grows larger and larger. For a moment is caught a glimpse of a circle with a double rim; the next moment before the eyes of the astonished spectator is whirling a thin transparent circular plate of glass, which but a few minutes before was lying in the glass pot.

A flat circular disc, nearly sixty inches in diameter, or sometimes more, is produced, of almost uniform thickness, except at the point of attachment to the ponty, where there is a swelling called the bull's-eye. Still whirling, the table, as it is now called, is carried off, laid flat upon a support called a *whimsey*, detached by shears or otherwise from the ponty, and lifted into the annealing kiln upon a fork. As the bull's-eye or centre lump which the ponty has left behind it keeps each table from close contact with its neighbors, the air passes freely between them, and the annealing is completed with tolerable rapidity, varying from 24 to 48 hours, according to the number of tables in the kiln. From the kiln the tables are conveyed to the warehouse, having passed since their first exit from the pot through the hands of ten distinct workmen.

The improvement in the details of the operation have produced a different result from that of former times.

In the warehouse, the tables are laid upon a *rest* or

cushion, and are divided by the diamond of the splitter into two unequal parts, the larger half containing the bull's-eye. The diameter of the table is measured on the rest, the usual size being now about 54 inches, and weighing thirteen pounds; tables have been made as high as seventy inches, but the difficulty of manipulation, and the uncertainty of the result, render such sizes too costly to be general.

The splitter carefully examines each table before splitting, and turns it around until he has brought it into the position in which he may split it to the best advantage, announcing at the same time its quality.

IV. *Plate Glass.*—This glass is formed by being cast or founded upon a smooth table, while in a liquid state, and is totally independent of the process of blowing. It is not generally known that originally all plate glass was made by blowing, and not until 1773 was this glass cast in England, while in France the process has been used for one hundred years. The method formerly adopted was the same as the blown sheet glass; the plates then produced were much smaller than can be executed by the casting process, which sometimes exceed ten feet in length, and about half an inch thick. Plates have been cast as much as fourteen feet long by eight to ten in width. The principal consumption of plate glass is for mirrors.

In composition this plate glass is similar to crown and sheet glass, the only essential bases being lime and soda; the plate glass has the soda in excess, for the reason that it imparts a higher degree of fluidity, and because the impurities which it contains are more readily dissipated by the heat, so that the use of soda,

though objectionable as tending to color the glass, facilitates both the fining and casting.

Plate glass consists by analysis of—

Silica,	75.9
Alumina,	2.8
Lime,	3.8
Soda,	17.5

It differs considerably from window glass in the proportions; it is, therefore, more fusible, more readily altered, and less hard than window glass, and it is also less brittle, and less liable to be devitrified.

The French plate glass consists of—

Pure sand,	100	lbs.
Sal soda,	35	"
Lime,	5	"
Broken glass,	100	"
Decoloring matter,	1	"

Another French formula is:

Sand,	100	lbs.
Sal soda,	60	"
Carbonate of lime,	13	"
Broken glass,	100	"
Peroxide manganese,	1	"
Pulv. smalt,	½	"

The English formula is:

The best washed sand and dried,	720	parts.
Alkaline salt of 40 p. c , soda,	450	"
Slaked and sifted lime,	80	"
Nitre,	25	"
Broken glass,	425	"

This whole mixture of one pot of metal yields one thousand and two hundred pounds of glass. The main object of getting a fine metal is by giving the most perfect transparency to mirrors, and to destroy the slightest traces of coloration; not alone must the metal or melted glass be thoroughly fused, but the original materials must be selected with great care. The sand must be very white and fine; flint and quartz reduced to fine powder will suit well; the soda perfectly pure, so as to avoid the green tint which soda is apt to impart.

The melting and fining is performed in two sizes of pots; the larger is for melting the vitreous mixture and for keeping it long in a state of fusion; the smaller for receiving a portion of the glass to be fined and cast, called cuvette or cistern. Furnaces for casting plate glass are constructed to hold six pots and twelve cuvettes, eight small and four large ones; the small ones have the form of a perfect square, the large ones of an oblong rectangle.

The ingredients for plate glass are fritted before melting, and then put in the pots in three successive charges; the material is left sixteen hours, and during the melting of the mixture in the pots, the cuvettes are placed empty in the furnace, but as soon as the whole charge is in a state of fusion, the cuvettes are removed by means of tongs and cleansed from all impurities by a scraper, and are placed in the furnace, and after a few minutes heating, the ladling or transferring operation commences. The surface of the metal in the pots is skimmed, and the liquid glass is transferred into the adjacent cuvette with a copper ladle, care being taken not to disturb any grains of

sand or lumps that may have settled down on the bottom of the pot. The ladling is performed by two men; each draws out the glass three times, and then plunges his ladle into cold water. The furnace is then shut, and the cuvettes are left to themselves for the glass to fuse, or the bubble sproduced in the mass by the process of ladling or tréjetage may be disengaged, and the excess of soda entirely volatilized. The melting lasts sixteen hours, and the fining also as long, and extends from 24 to 48 hours, or until all the bubbles are dispersed, and until specimens of the glass exhibit in every respect a fit state for casting.

The casting process is as follows:

While the glass is acquiring the requisite consistence, the annealing furnaces and the slabs or metal plate upon which is to be received the liquid glass, must be heated. The casting slab is now made of iron, and as large as to weigh 50,000 pounds, and cost 100,000 fcs., and is from 10 to 20 feet in length, and the same in breadth, and from 6 to 7 inches thick, and rests on a strong wooden frame, movable on castors, or a rail-road, and is wheeled from one annealing furnace to the other. The height of the slab is made exactly on a level with the floor of the arch of the annealing furnace; its upper surface is flat and polished, to mould the lower surface of the mirror, and before the casting it is heated by hot coals spread over it, and then wiped perfectly clean.

The annealing ovens being heated to a brown red, the casting slab brought to a suitable temperature, and the metal or melted mass thickened to the requisite point for flowing readily and equably, the aperture

into the cuvettes, which are to be taken out, is then opened, and two workmen introduce tongs into the furnace, and grasp the cuvette by the groove, while a third slides a large pincer under it. When that instrument is pushed well under the bottom of the cuvette, the workman draws it towards him, aided by the others with their tongs, which are supported on rollers; in this manner the cuvette is drawn to the mouth of the opening, where it is raised by a crane, placed upon a truck or low carriage, and removed to the casting table; the melted glass being skimmed, the cuvette is then drawn up to a sufficient height by a tackle, and suspended above the upper end of the casting table, where it is tilted over by means of the tongs, and the metal is poured out on the table. The appearance presented by the molten sheet is now exceedingly splendid; the glass is prevented from running over the sides by ribs or rims of copper, which are exactly equal in height to the intended thickness of the plate of glass, and when the cuvette has been emptied of its contents, a massive hollow copper cylinder, three feet in diameter, and resting on each end on the side ribs, is set in motion. This cylinder, which weighs several hundred weight, is moved by means of the handles, which form a prolongation of the axis, and spreads the glass out into a sheet of uniform breadth and thickness. To prevent any impurity from contaminating the glass, a workman draws the washer covered with cloth immediately in front of the advancing sheet of fluid glass, the excess of glass pours over the front edge of the slab into a trough filled with water, and finally the roller passes off, and is received in the grooves.

A beautiful play of brilliant colors, comprising every tint imaginable, is exhibited by the glass immediately after the roller has passed over it, probably caused by a temporary oxydation of the surface. While the introduction of the plate into the annealing furnace is being proceeded with, other workmen are engaged in taking from the fining furnace another cuvette, which arrives at the casting table at the moment when the preceding plate has just been introduced into the annealing oven. After filling the oven, all the openings are carefully stopped up with iron plates and clay mixed with sand. At the end of twenty hours some of the pieces of iron are taken away; an hour or two afterwards more are removed; as the oven cools, more and more are taken away, and at last the whole of the clay and plates of iron which stopped the apertures are removed. When the hand can be placed on the glass plates without feeling much heat, they may be taken out of the oven.

The plates, after being withdrawn from the annealing oven, have to undergo the operation of *squaring*, *grinding* and *polishing*; as taken from the oven, they are about half an inch thick, and present an irregular mottled appearance, roughened on the lower surface by the sand on which they have rested, and smoother, but not flat on the upper surface. The first process is that of squaring, or cutting them into their useful dimensions, and the workmen endeavor, notwithstanding the imperfect transparency of the glass, to select those which appear to be free from defects, while such as show imperfections that cannot be removed by grinding, are picked out to be cut into smaller plates.

The squaring is performed by passing a rough diamond along the surface of the glass, guided by a square rule; the diamond cuts to a certain depth into the substance, when, by gently striking the glass with a hammer underneath the part which is cut, the piece comes away, and the roughness of the edge then left is removed by pincers. The plates having been squared, undergo then the process of grinding and polishing. Two plates are employed, one of larger dimensions, and one three or four times smaller, which are made to rub against each other, which is done by machinery; the lower and longer plate is imbedded in Plaster of Paris in a perfectly horizontal position upon a table about two feet high, termed the *grinding bench;* the smaller plate is cemented upon the lower face of a swing table, made heavy by weights, and caused to traverse over the lower plate in such a way that by a combination of a rotary and oscillating motion, the relative position of the two plates is constantly changed. In adjusting the plates, a rough or rolled surface of the one is opposed to the comparatively smooth or casting plate surface of the other, and the material employed to grind the surfaces is thrown upon the lower plate from time to time; ground flint of different sizes is used for this purpose; the machinery is set in motion by a steam engine, and the process is continued until the ground plates exhibit a perfectly horizontal and even, though still unpolished surface. When one side of the plate has been sufficiently ground, it is loosened from the frame and turned over, so as to present the other surface to be ground in the same manner. Some degree of pressure is employed, by loading the upper plate with weights,

as the grinding of each side approaches to completion. The process is now performed in less than three days. The plates require now another polish, which is done by grinding them with emery powder of increasing degrees of fineness; after the application of the last or finest emery, the plate has become quite smooth and partly polished. The glass, although now perfectly even, appears opaque and deadened on the surface, and still requires the final polishing. To effect this, a piece of wood is covered with numerous folds of woollen cloth, so as to form an elastic cushion, which is fitted with a handle; the plate is imbedded in Plaster of Paris, as already stated, and the cushion being wetted, is covered with a fine earthy matter consisting of *crocus martis*, and is moved backwards and forwards on the surface of the plate with considerable pressure. By the grinding and polishing, the plates are reduced as much as one-third, and if any radical defects exist in the glass, these are only heightened by the polishing; those which are still found defective after the polishing, are cut up into smaller plates and polished again, while the perfect ones, when destined for mirrors, are subjected to a final process, which is the silvering of mirrors, which is done by a compound of tinfoil and mercury. The operation is commenced by spreading a sheet of tinfoil, which must be of somewhat larger dimensions than the plate to be covered, upon a flat stone or slate slab, termed the silvering table, and brushing mercury over it. When the surface of the tinfoil is uniformly covered, more mercury is added, till it covers the metallic sheet to the depth of one-sixth or one-quarter of an inch. This process is also a tedious one, and very

dangerous for the workmen, and a new process has latterly been substituted, by employing a *silvering fluid*, obtained by mixing ammonia with nitrate of silver, and adding to it an alcoholic solution of some essential oil, like oil of cloves, cassia, &c., with a certain portion of grape sugar; this fluid has the property of depositing bright metallic silver, on the addition of the reducing liquid, consisting of the alcoholic solution of one part oil to three parts alcohol, and two parts grape sugar. Another reducing liquid is composed of

2	parts of	nitrate of silver.
3	"	water.
1	"	ammonia.

To this mixture is added one-fourth part of grape sugar, dissolved in weak spirit. For coating the interior of glass balls, &c., gun cotton, dissolved in caustic potassa, with the aid of heat, adding to the brown solution a few drops of nitrate of silver and the ammonia, until the precipitated oxide of silver is re-dissolved; this mixture is introduced into the glass ball or other vessel to be loricated, and heated in a water bath, when, after a certain time, the mixture becomes blackish brown, froths up and deposits all the silver upon the glass, forming a mirror which is said to reflect the light with surpassing brilliancy. The latest method, however, is used by adding a certain quantity of Rochelle salt, in solution, to the ammoniated silver of the above proportions, without the aid of grape sugar or oil of cloves.

Petitjean's Method of Silvering Glass.

For one hundred superficial feet of plate glass, a mirror was completed in forty hours, while the operation usually occupied ten days.

Prepare two argentiferous solutions; the first has 180 parts of nitrate of silver, which, treated with 62 parts of liquid ammonia of 870° spec. gravity, and 500 parts distilled water, the whole is then filtered; this solution is afterwards diluted with sixteen times its volume of distilled water, to which is added drop by drop seven parts of tartaric acid, (Rochelle salt has been employed in this country and found preferable,) previously dissolved in thirty parts of water; this liquid is marked No. 1 solution.

The second solution is prepared precisely the same, only containing double the quantity of tartaric acid or Rochelle salt.

The plate glass being cleaned with putty powder mixed with water, and spread over the entire surface with a ball of chamois leather, or a soft linen cloth, and leaving it to dry for a few minutes, and then rubbing it off with another piece of chamois, the glass is placed on a rack, and an India rubber roller, moistened with distilled water, passed over it, to remove any particles of rust that may adhere to it. After this, it is laid upon a metallic table, covered with a wax or varnished cloth, and heated to about 120°. The plate being in a perfectly horizontal position, its surface is covered with No. 1 solution; the deposition of silver commences in about ten minutes, and is completed in fifteen minutes afterwards. The glass is then tilted up, so as to allow the liquor to run off, and

rinsed with water more than lukewarm, to carry away the non-adherent powder. It is then restored to its horizontal position, and covered with No. 2 solution. In a quarter of an hour the deposit is completed. It is now washed as before and dried, after which it only remains to polish and burnish the film of silver deposited, in order to make it perfectly smooth, and give closeness to the grain.

In the last Paris Exhibition, the finest specimens of plate glass were exhibited; one plate measured twenty feet by twelve feet; one silvered mirror of nearly the same size; the glass for them, and several other plates, was melted in a single pot, capable of holding a ton of the fused metal. The tin foil used for silvering weighs two pounds for every square meter.

A large mammoth plate glass was lately imported from France, which measured twenty feet long and sixteen feet eight inches wide; it is not intended as a mirror or window, but to represent, under a strong light, a frozen lake in a theatrical scene.

V. *Flint Glass.*—This is generally termed crystal glass, on account of its resemblance to rock crystal, the natural mineral; it is chiefly manufactured into articles of domestic use and ornament, such as tumblers, decanters, wine-glasses, vases, drops for chandeliers, &c. In consequence of its great transparency and high refractive power, it is also formed into lenses for optical instruments. It is also called flint glass, on account of the employment of the flint, which is found in the chalk, as the source of the silica; for the sands are not only more free from iron, but less expensive in the preparation than flints, when washed and calcined. The flint glass, properly speaking, is a

lead or metal glass, in distinction from the other varieties of glass, and is distinguished from crown and plate glass by the use of potassa, instead of soda, in the manufacture.

The term crystal, or flint glass, is now known to denote the double silicate of potassa and lead. It is well understood that the colorless crystal, or lead glass of the present day, or, in other words, a crystal possessing that quality, which constitutes its chief beauty and value, is entirely of a modern invention. The analysis of the flint glass gives—

Silica,	56.0
Lime,	2.6
Oxide of lead,	32.5
Potassa,	8.9
	100.0

Many metallic oxides are capable of combining with silicic acid, and thus furnishing silicates which readily mix with alkaline silicates, but almost all these are colored. Till lately, the protoxide of lead and the oxide of bismuth were regarded as the only oxides capable of yielding silicates with little color, and consequently colorless glasses, by their mixture with the silicate of potassa in a proper proportion ; but a glass of zinc, which had a very pleasing and white appearance, and was specially suited for achromatic purposes, has been shown to have the remarkable property of being of greater specific gravity, and much more pure and pellucid than lead glass.

Well prepared crystal or flint glass is almost without color, is more transparent, more brilliant, and

heavier than plate or window-glass. It excels the fine Bohemian crown glass in refractive power and easy fusibility, although the latter is harder and more completely colorless. Flint glass of not less than the usual density of 3.200, well polished, is considered the nearest approach to the diamond ; it owes its brilliancy and high density to the silicate of lead ; but as the latter is in itself yellow, it communicates a yellow tint to the crystal, when it preponderates over the alkaline silicate beyond a certain limit.

It is a common mistake to suppose that great density or weight is an advantage in crystal for articles of common use ; it is, on the contrary, a real inconvenience, and in the most favorable view, can only be considered as a ready means of showing that the crystal or flint glass contains enough of silicate of lead to impart to it all the other qualities, which give it its peculiar value, and renders it preferable to other glasses for certain purposes. As lead affords the only metallic oxide which is usually employed in the manufacture of flint glass, so potassa is the only alkali which can be successfully associated with that ingredient to yield a colorless glass. The silicate of soda always communicates a blue or green tinge, which would become more perceptible and disagreeable in the thick articles usually manufactured of crystal. Crystal vessels are generally intended to receive mouldings, or cut ornaments, and do not admit of being made thin in the sides. The annealing would also become difficult in vessels of considerable size, without a proportionate thickness. Crystal is so fusible, that it is not easy to prevent such articles from sinking in or collapsing during the annealing. This kind is, therefore,

exclusively confined to the manufacture of thick articles, and hence it is only the colorless silicates that can be used, namely, those of lead or zinc, and potassa.

A good common flint glass is the following two formulas, the one with coal, and the other with wood as fuel:

	COAL.	WOOD.
Sand, washed and calcined,	100	100
Red lead,	70	45
Purified potassa,	30	35
Cullet,	100	100
Saltpetre or arsenic,	2	2
Oxide manganese,	3	3

A highly pellucid and transparent flint glass is obtained of—

Carbonate of potassa,	one	hundred	weight.
Red lead or litharge,	two	"	"
Sand, washed and burnt,	three	"	"

Saltpetre, from 14 to 28 pounds.
Oxide manganese, from 4 to 12 ounces.
Cullet at discretion.

The best French formula is—

Pure sand,	300	parts.
Red lead,	215	"
Purified carb. potassa,	110	"
Nitrate of potassa,	10	"
Borax,	12	"

The lowest proportion of red lead that can be used, is in the following formula:

Sand,	300	parts.
Red lead,	180	"
Carb. potassa,	120	"
Cullet,	300	"
Arsenious acid,	45	"
Oxide manganese,	60	"

The utmost attention must be paid to have the materials in a perfect state of purity; the sand should be very white, and free from coloring oxides of iron and manganese; it ought to be washed with diluted hydrochloric acid, and undergo eight washings of water, and afterwards pass through a heated coil called a calker, so that it is perfectly dry. The carbonate of potassa requires likewise a thorough purification, by dissolving it in water, decanting the clear solution, and evaporating to dryness. The red oxide of lead must be made from pure metallic lead, for the commercial is never perfectly pure, but contains copper, iron and other oxides in too large a quantity. The few ounces of manganese are employed to neutralize the greenish tint produced by the presence of iron or other impurities. The flint glass furnaces are generally round, and contain from eight to twelve pots.

It is also advisable to have two furnaces, instead of one, both opening into the same flue, for the reason, while one of the furnaces is in full operation, the other may be undergoing repair; or the working of one may be entirely suspended, without injury to the other, during a dullness of trade. Each of the furnaces may be capable of holding eight pots. Their shape is distinguished from those employed for other descriptions of glass, by being covered with a hood-shaped

top, the mouth of which fits the working holes of the furnace, so that the smoke and heat cannot escape in the same way as in the usual glass furnaces.

In France open pots are used for flint glass, and as fuel, dry beech or oak wood; so little carbon is produced from the smoke as not to affect materially the metal, although the flames play upon its surface; but when coal or coke is used, the fumes and smoke emitted would carbonize or deoxydize the lead, and precipitate it to the bottom in the original metallic state, if the pots were not covered; besides that, the solid particles of soot would blacken the glass, by attaching themselves firmly to its surface.

The melting pots usually hold about 1,800 weight each, and the batch or frit is introduced in them by means of shovels in quantities of four hundred weight at a time, allowing a sufficient interval between each filling for melting down the various charges, until the pot is entirely filled with fused glass. In about twelve to fifteen hours every pot in the furnace is fully charged with liquid metal; air bubbles and striæ then abound, and are not expelled until thirty or forty hours more have elapsed, when the mass becomes homogeneous. The best results depend upon an intense and continuous fusion, for too little caloric will fail to refine the metal.

During the founding, the mouths are securely stoppered and clayed up; the shorter the time of fusion and refining the better; for this purpose the heat can scarcely be too great.

If the glass does not get fine by the usual time allotted, but becomes cottled or gelatinous, it never will recover, however urged by subsequent fusion; such

glass must be ladled into water, and considered only as cullet, for a re-fusion with a proportion of new materials. The moment the metal is fully fused and refined by còntinuous rapid fusion, the high temperature of the furnace should be reduced from its maximum heat to a working temperature, this period being considered the *crisis*.

The mechanical operations connected with common bottle glass, crown, sheet and plate glass, are uniform in their character; the description of the making of one bottle, or of one table, sheet or plate glass, applies to all; the infinite variety of shapes into which common flint glass or crystal is manufactured, would be very tedious to explain. That glass is either formed by simple blowing with the pipe, and then shaping by hand or by blowing in moulds, or by moulds alone, in which the glass is subjected to pressure. In each of these cases the form and appearance of the articles are mostly improved by grinding, cutting, &c.

A tumbler, for instance, may be made by hand. The workman collects on the end of a pipe a small quantity of glass, which is now rounded on the marver, expanded by blowing, or somewhat elongated by swinging, when it assumes the pear form; the pipe is then suspended vertically, and the glass is allowed to drop by its own weight upon the marver, which flattens it at the extremity, and being at the same time further blown, assumes a bottle form. The pipe, with a portion of the glass, is then detached, by touching the piece with a cold pucellas; this contracts and slightly fractures the glass, which is subsequently cracked through the entire circumference by a smart blow of the same instrument. In the meantime the

ponty has been attached by adhesion to the flat end, and the other end is first expanded with the pucellas, and then sheared off so as to make it perfectly even, and fit it for the flashing or finishing; finally, it is knocked off from the ponty by a sharp blow, and taken to the annealing arch. Wine glasses are usually made in three pieces, but the process is the same as for tumblers. The moulds for flint glass are carefully constructed of brass or iron, and when of simple construction are somewhat wider at the upper end, so that the pieces may be easily removed, or are composed of more than one piece, when projecting parts are to be moulded. A common open and shut mould, as is used for apothecaries' vials, as well as for common wine bottles, are formed by two halves, connected with a bottom hinge; the glass to be moulded is gathered on the pipe, rolled on the marver into a cylindrical form, and then pinched with the pucellas at the end attached to the pipe, to form the neck of the bottle; the cylindrical mass, still adhering to the pipe, is then inserted into the mould lying on the ground, its two halves are shut, and the workman blows through the tube, which renders the mass of glass hollow, while it receives from the mould the external form required.

The third method of manipulation with flint glass, is moulding by pressure, which consists in dropping the soft metal into a prepared die, and then pressing down the matrix or plunger upon it by means of a lever.

The finishing process given to the finer articles manufactured of flint glass is the *cutting* and *polishing*, or more properly *grinding;* this operation is performed by discs of iron, sandstone or copper, revolving

in a lathe, which is usually propelled by steam; the edges of the discs, which are sharp, angular or rounded, according to the work to be performed, are supplied with sand and water dropping from a hopper for rough grinding, and with emery for fine grinding. A stone wheel with water is employed to smooth out the rough sand marks, and prepares the glass for the polishing, which is effected by means of a willow-wood disc, first with a mixture of pumice and rotten stone, and finishing with a preparation of tin and lead or glass putty; all table glassware and hollow articles are thus cut. Chandelier drops are cut or ground with iron and stone wheels in the same manner, but are finished with a lead wheel, supplied with fine rotten stone and water.

Small copper discs of the size of a half-penny and finely pulverized emery mixed with oil are used to execute the outline and ground of the glass engravers' work, and for polishing, lead wheels and very finely pulverized emery are employed. Coarse patterns for hall lamps are engraved by the glass cutters' smoothing wheels. For inscribing initials, coats of arms and minute designs, very small discs must be employed. The finest incisions are made with copper pencils, either pointed or ending in a button-like disc.

The *etching on glass* is performed by hydrofluoric acid, either in the gaseous or liquid state, and exerts a peculiar action on glass, which has been turned to account as a substitute for cutting or engraving designs. For *etching* on glass by means of hydrofluoric acid, the glass is cleaned and a melted varnish poured upon it, which is spread in a homogeneous coating; the varnish is formed of wax and turpentine, say one part

of the latter to four parts of wax; a burin is then passed over the varnish, following the lines of the figure and cutting through the varnish to the glass; when the figure is traced, the glass is ready to be exposed to the action of the hydrofluoric acid, which, according to the strength, requires from five seconds to five minutes; the varnish is then removed by melting it with heat, and the glass is then wiped off with a soft linen rag. A finer varnish is required for more delicate designs and shades, which is a fat copal varnish, blackened with lampblack, which must be quite fine, and sprinkled with oil of turpentine; the coatings laid on must be very thin, and each should be quite dry before putting on a new one. The glass is sufficiently covered with varnish when the light can scarcely be seen to pass through it; the design is then copied through, and the varnish is removed from the lines with the points of gravers, or simple needles, of different sizes and forms. This portion of the glass enables one to perceive the most delicate lines. After having formed the figure, it must be corroded out with liquid hydrofluoric acid. By a preliminary experiment or a coin-strip of glass, the time will be easily ascertained, which is required to be used on the article when the design is to be executed. Hydrofluoric acid, diluted with soft water, one part of the first to six parts of the latter, is unquestionably the best material for cleaning plate glass and any other glass which may be sooty, or have any flaws on the surface.

Optical Glass.—The most serious difficulty, which has to this day impeded the progress of improvement of optical instruments of the highest order, has been the imperfection of glass. It is one which is so far

from betraying to ordinary observers the faults, which make it useless to the optician, when the specimens which seem most brilliant are not seldom those which are in this respect most faulty. Two kinds of glass, crown and flint glass, are combined in the construction of achromatic lenses. Crown glass is only composed of silex, potassa and lime, while in flint glass the oxide of lead is added. The unequal density of these two glasses prevents their forming, while in a state of fusion, a mass of uniform character; the heavier of the two tends to sink to the bottom of the crucible, and the result is to produce a compound of very unequally refracting power. Nearly fifty years ago the great English philosophers, Faraday, Herschel and Dollond, entered into experimental inquiry, for the purpose of devising means of overcoming such a great difficulty; which, however, did not advance the practical object in view, although the results of their investigations were, in many respects, highly interesting. The largest telescopic objective of satisfactory performance did not exceed five to six inches in diameter. At the Paris Exposition of 1867, the most brilliant display of optical glasses was exhibited, which have quite satisfactorily proved the equal density and uniformity of refractory power. The process is made known to consist of uniting numerous small selected masses of glass of ascertained equality into one large mass by pressure, while in a plastic condition; it resembles the process of the welding of iron, and the great problem is now fully solved. The same manufacturer exhibited several specimens of the silico-borate of lead, a glass of great specific gravity, and which he calls *heavy glass*, its specific gravity varying from 4.20 to 5.44.

A great magnificent disc of flint glass of over twenty-eight inches was also exhibited. At the same Exposition a great variety of glass plates were exhibited; one of them, by actual measurement, was found to have the dimensions of nineteen feet and six inches by eleven feet.

The exhibition of prisms was very excellent; very large four inch right-angled prisms, and some rock crystal prisms, suitable for the study of the fluorescent rays beyond the violet; also, hollow prisms for experiments on transparent fluids, were formed of plates of plain glass united without cement, being made water-tight by the perfection and polish of their surfaces.

For illustrating the laws of refraction, were prisms with horizontal axes of variable angles for fluids.

The best proportions for an optical glass are the following:

For flint glass:

Sand,	43.5
Red lead,	43.5
Carbonate potassa,	10.
Nitrate potassa,	3.
	100.

For crown glass:

Sand,	60
Carbonate soda,	25
Carbonate lime,	14
Arsenic,	1
	100

It will be observed, that optical flint glass is chiefly distinguished by the large proportion of lead which enters into its composition ; its density should not be lower than 3.6 at least. The essential point in the manufacture, however, consists in the constant stirring of the metal during the melting and fusing. The superiority of Guinaud's plan is considered not to have been in the novelty of the materials or proportions, but in carefully agitating the liquid glass while at the highest point of fusion, *then cooling down the entire contents of the pot in a mass*, and when annealed and cool, separating unstriated portions by cleavage. Faraday's heavy glass, which has proved so important in experiments connected with the polarization of light by magnetic action, is composed of the following ingredients :

Protoxide of lead,	104
Silicate of lead,	24
Dry boracic acid,	25

This glass required but a red heat for fusion, thereby offering facilities for minute agitating operations ; it was found, however, not to be durable, and not calculated for application to optical purposes or general use.

Zinc Optical Glass.—The basis of this vitreous compound is the oxide of zinc, a certain quantity of borax or boracic acid being added to give the glassy character for which the boracic compounds, no less than the silica, are so eminently remarkable, combined with an easier fusibility ; it is suitable for the crown glass in achromatic telescopes, but not for the flint glass ; the

low dispersive power of the zinc compound, points to the use of glass of zinc for this purpose.

VI. *Strass and Colored Glass.*—The manufacture of glasses tinged, colored or stained by different processes, has become a business of great and growing importance. The taste for stained glass windows, which formed so distinguished a feature in the history of a former period, has revived, and is now displayed in the decoration not only of splendid palatial and ecclesiastical structures, but even of many private dwellings, steamers, &c. The skill of the Venetians of a former day in producing colored vases and other ornamental articles of glass of every variety of hue, is equaled, if not surpassed, in modern times; artificial gems or pastes, which are true glasses, are now formed, that emulate, if they do not eclipse in sparkling lustre and pure transparency, the rarest and most beautiful natural productions of the mineral kingdom.

The basis of the color, or that with which the coloring matter is actually mixed, is a lead glass, and this, when real glass painting is the object, is applied either as a pigment, or in a melted state on common glass or some other finished article; in other cases the colored lead glass is itself formed, cut or moulded into the finished article. When the latter is an artificial gem or paste, a peculiar glass is employed termed *strass*, which it may be proper to describe now. This paste, having its name from the inventor, constitutes the only true glass not yet hinted at in this treatise, but forms the basis of artificial imitations of precious stones. For this purpose a glass is required, possessing the highest degree of purity and transparency, combined with the greatest possible lustre. These

requirements are found in a composition analogous to that of flint glass, but containing a much larger proportion of oxide of lead and a little boracic acid. The three following mixtures are recommended:

	ONE.	TWO.	THREE.
Ground rock crystal,	100	—	100
Sand,	—	100	—
Pure red lead,	156	—	154
White lead,	—	171	—
Purified caustic potassa,	54	32	56
Boracic acid,	7	9	6
Arsenious acid,	3	3	16

The oxide of lead is in excess of all other glass, even optical flint glass. When strass is well prepared, it possesses as nearly as possible the high refractive power, and all the other properties of the diamond, except its hardness. When cut into shape without any coloring, it answers for imitating the diamond; and when tinged by silicates with metallic bases, it furnishes imitations of all the colored stones.

Its perfect purity and high lustre are the essential requisites, and for this reason requires great care in the choice of the materials. A pottery furnace and Hessian crucibles are used for melting the material, which is to be kept in the fire for twenty-four hours; the more tranquil and prolonged the fusion, the greater hardness and beauty does the strass acquire.

The coloring materials used for the imitation of gems, are the following:

Yellow is produced either by charcoal, antimony, silver, or oxide of uranium; a very superior yellow,

by roasting the sulphide of antimony to the state of antimonious acid, or the white oxide of antimony, and melting it with from three to five per cent. of undecomposed sulphide of antimony. An orange yellow is obtained by glass of antimony, red lead, and a little oxide of iron; in these cases the substances so prepared are mixed with the materials of the glass. When silver is employed, the process is quite different. In this case a mixture of powdered clay and chloride of silver is applied to the surface of the ready-made articles, and on reheating these in a muffle, the silver penetrates to a certain depth into the glass, even before the latter softens; the article is then allowed to cool, and the coating which was applied is scraped off, when a yellow color of great purity and brilliancy appears on the glass; very remarkable it is that this effect can only be produced on glass containing alumina, which shows that it is a chemical, and not mechanical action. Oxide of uranium produces a beautiful delicate yellow of a slightly greenish hue. Red of different shades is communicated by oxide of iron, sub-oxide of copper, or different preparations of gold, mixed with other materials; the oxide of iron is employed, either as pure oxide, prepared by heating the nitrate, or in the state of red hematite or ochre; it produces, if added to the glass mixture, a cheap and very common brownish red. The peculiar action of sub-oxide of copper was much employed by the artists of the fifteenth and sixteenth centuries, for producing the brilliant red colors of window panes; and in later times the glass so colored was supposed to be indebted to gold for its beautiful rich hue. So intense is the

coloring power of this oxide, that even a very small quantity reddens the glass so much, as to render it opaque, and hence it is almost impossible to command any desired tint in applying it; recourse is had, to obviate this difficulty, to the process of *flashing*, or coating with colored glass.

The application of gold for producing a brilliant red color, which can be made to assume a scarlet, carmine, rose or ruby tint, has long been known, having been made by precipitating a solution of chloride of gold with a salt of the sesquioxide of tin, under the name of *cassius purple;* the simple addition of a solution of gold to a flux, without any oxide of tin, is, however, capable of producing rose and carmine colored glass.

Blue is produced by oxide of cobalt, a pigment which is equally applicable to lead glass and to glass containing no lead. The coloring power of the oxide of cobalt is so intense, that pure white glass is made sensibly blue by the addition of one thousandth part of the oxide. Smalt and zaffre are but impure oxides of cobalt.

Green is produced either by protoxide of iron, protoxide of copper, or oxide of chromium. The tint produced by the first has little brilliancy. The oxide of copper gives a beautiful emerald; for this purpose the glass is mixed with the product obtained by heating copper to redness with access of air, or with powdered verdigris, which is then decomposed in the fire and converted into oxide by oxydizing agents. Care must be taken to prevent the protoxide of iron from being converted into sesquioxide, and the oxide of copper from being reduced to sub-oxide.

Artificial Gems.—The following is a formula for the production of artificial gems:

Diamond.—Colorless strass without any addition.

Topaz.—White strass, 1000

Clear orange red glass of antimony,	40
Purple of cassius,	1
Also of strass,	1000
Oxide of tin,	10

Ruby.—This is the rarest and most highly priced of artificial stones; the mixture for topaz often gives an opaque mass, translucid at the edges and presenting in its thin plates a color red by transparency. One part of this opaque mass and eight parts of strass, melted in a Hessian crucible, when left 30 hours in the fire of a potter's furnace, give a fine yellowish crystal similar to strass. Remelted with the blow-pipe, this produces rubies of the first water. A ruby not so fine and of a different tint may be made by employing the following proportions:

Colorless strass,	1000
Oxide of manganese,	25

Emerald.—It is very easy to imitate; the mixture of oxide of copper with colorless strass gives the best results, and if oxide of cobalt is added, the green obtained presents blue reflections.

The composition which gives the best imitation of natural emerald is as follows:

Colorless strass,	1000
Pure oxide of copper,	8
Oxide of chromium,	0.2

By increasing the proportion of chromium or oxide

of copper, and adding oxide of iron to the mixture, one may vary the green shade, and imitate peridot or dark emerald.

Sapphire.—To produce a fine oriental blue color, one must employ very white strass and very pure oxide of cobalt. The composition, put into a luted Hessian crucible, should remain 30 hours in the fire. The proportions are as follows:

Colored strass,	1000
Oxide of cobalt,	15

Amethyst.—The color of this stone must be fine and velvety, to be of any value. The formula which succeeds best is the following:

Colorless strass,	1000
Oxide of manganese,	8
Oxide of cobalt,	5
Purple of cassius,	0.2

Aquamarine.—It is of pale emerald tint, but the most valuable kind is colorless like the diamond. It is obtained artificially:

Colorless strass,	1000
Glass of antimony,	7
Oxide of cobalt,	0.4

Syrian Garnet or Carbuncle.—It has a lively color, and is much used for small jewels. The artificial garnet is a kind of dark ruby, and is made after the following formula:

Colorless strass,	1000
Glass of antimony,	500
Purple of cassius,	4
Oxide of manganese,	4

In the manufacture of artificial stones, there are many precautions to be taken, and many points to be observed, which can only be acquired by experience. The materials must be finely pulverized. The mixtures can only be well made by repeated sifting. To obtain masses well melted, without any striæ or bubbles, it is necessary to employ the purest substances, to use the best crucibles, to melt with a graduated heat in a furnace which is quite equal to its maximum temperature, to leave the metal in the furnace at least from 24 to 30 hours, and to cool the crucibles very slowly, that their contents may undergo a kind of annealing.

Soft White Enamel.—To 600 weight of batch add twenty-four pounds of arsenic and six pounds of antimony.

Hard White Enamel.—To 600 weight of batch add 200 pounds of putty prepared from tin and lead.

Blue Transparent Glass.—To 600 weight of batch add two pounds oxide of cobalt.

Azure Blue.—To 600 weight of batch add six pounds of oxide of copper.

Ruby Red.—To 600 weight of batch add four ounces of oxide of gold.

Amethyst or Purple.—To 600 weight of batch add twenty pounds of oxide of manganese, (pure.)

Common Orange.—To 600 weight of batch add twelve pounds of iron ore and four pounds of manganese.

Emerald Green.—To 600 weight of batch add twelve pounds of copper scales and twelve pounds of iron ore.

Gold Paper Color.—To 600 weight of batch add

three pounds of oxide of uranium. Under a batch is understood the mixture of materials, such as that for flint glass as noticed in previous pages.

Flashing and Casing.—Referring to the sub-oxide of copper, it was remarked that the coloring power was so intense, that even a very small quantity would render the glass opaque, and that the process of flashing had to be resorted to, in order to overcome the difficulty. This process consists in coating a layer of colorless with one of colored glass, which can then be reduced by grinding to the proper tint. For this purpose the glass-blower collects the proper quantity of colorless glass on the end of his pipe, rolls it upon the marver, and then dips it for a moment into a pot of melted colored glass, and blows out the two together into a cylinder or globe, which is flattened or flashed out in the usual manner, which is the way how panes for the glass painter are formed, which consist of two layers of glass, one colored the other colorless, and the former can be ground down to any required tint or degree of transparency. An ingenious application of this process is made to vessels of flint glass, which are colored on the outside in a similar manner, and colorless edges or facets are then produced by cutting through the outer layer of colored glass into the substratum of colorless glass.

Flint glass is colored in a similar manner, by the process called casing, in the following manner: If any two or more glasses intended for casing have been mixed of the same specific gravity to give them the capability of harmonizing, that is, of contracting and expanding equally, the blower has to gather a ball of solid glass intended for the interior layers in the usual

manner, which may be considered to be of white crystal glass; about the same time his assistant prepares a casing of colored glass, knocking off the knob to open and shape it, somewhat like the bowl of a wine-glass, or the broad end of a large egg-shell; this is set in a metal stand on the floor, merely to steady the case or shell, while the blower takes the lump of flint or white glass, and gently blows it into the colored case or shell, to which it immediately adheres, and when submitted to a pot hole, it is found to weld perfectly.

Venetian Filagree work is produced in the following manner: Pieces of cane, or solid rods of glass of different colors, having been drawn out in the same manner as tubes, and whetted off to the required lengths, are arranged in the flutes or internal grooves of a cylindrical mould; the blower then inserts a solid ball of transparent flint glass, and the whole is exposed to a welding heat till the canes adhere to the ball; both are then withdrawn with it from the mould.

The *Venetian Ball* is simply a number of pieces of waste filagree glass collected together without regular design.

The *Millefiore*, or star work of the Venetians, is formed by placing lozenges of glass cut from the ends of colored filagree canes in the interval between two transparent canes.

Glass Mosaic is produced by threads or small canes of variously colored opaque or transparent glass of uniform lengths, ranged vertically side by side in single threads or masses, so that the ends shall form grounds agreeably to some prefigured design.

Venetian Frosted Glass is obtained by immersing the

gathering of hot metal in cold water, quickly withdrawing it, reheating and expanding it by blowing before it becomes so hot as to melt, and weld together the numerous superficial cracks produced by the momentary immersion in cold water; these cracks only penetrate as far as the metal has been cooled by the water, and remains as depressions until the article is finished.

Avanturin Glass is an easily fusible brown, or in thin layers, yellow glass, interspersed with spangles or numerous fine yellow laminæ with a metallic lustre, which give it a peculiar shining appearance. The manufacture was long kept a secret by the Venetians. It was commonly supposed that avanturin glass was produced by melting scales of metal or mica with the glass; but when examined under the microscope, these scales appeared as regular three or six sided tables, perfectly crystaline in structure; and it was ascertained that the spangles consisted of metallic copper crystalized in the form of flat segments of a regular octahedron. The following mixture, after fusing together for twelve hours, produce a good result:

Pounded glass,	300 parts.
Copper scales,	40 "
Iron scales,	80 "

The fused mass must be cooled slowly; the glass obtained is somewhat deficient of lustre, but it contained copper diffused through the mass in octahedral crystals.

Glass Painting.—Painting on glass is performed by means of a vitreous mixture termed the flux, com-

bined with a pigment prepared from some metallic oxide; the flux and oxide are simply that combination of ingredients which is necessary to produce a highly fusible colored glass of the required hue; this mixture is reduced to a state of fine powder rubbed up in oil of turpentine, boiled oil, or sometimes simply with water, and laid upon the glass to be painted by means of a brush; the glass thus painted or stained with the intended design is then exposed to a heat sufficient to vitrify the mixture of color and flux, without melting the glass; in other words, the painting is said to be burnt in, the ingredients of which it is composed are converted into a colored glass or transparent picture, while the pane or other article on which it is laid is only sufficiently softened to cause the complete adherence of the colored glass to its surface.

The fusing point of the pigment must be much lower than that of the glass to be painted; it is even necessary that the former should vitrify at a temperature at which the latter does not sensibly soften, for any considerable softening or yielding of the glass would distort the design; hence the manifest inapplicability of crystal on lead glass for painted articles, on account of its great fusibility. Common window or plate glass may be successfully used, and best of all, the hard Bohemian glass, which contains potassa for a base. The flux is usually composed of the following ingredients:

Quartz in powder,	100 parts.
Oxide of lead,	125 "
Oxide of bismuth,	50 "

But if these oxides exert an injurious action on the coloring matter, and tend to change its shade, the subjoined composition is used :

Quartz in powder,	100	parts.
Fused borax,	75	"
Nitrate of potassa,	12.5	"
Carbonate of lime, free from iron,	12.5	"

To each of these mixtures or fluxes the proper coloring matter is added, and the composition so formed is introduced into a crucible and melted into a colored glass; the latter is then reduced to a fine powder, mixed, as has been stated, with oil of turpentine, and used as a common pigment for painting on the less fusible glass. In this operation a cartoon, or drawing upon paper, is placed below the glass, and the colors are applied on the corresponding lines. In preparing painted sheets or panes of glass, brown or black outlines are generally traced on the one side of the sheet, while the colors are laid on the other side; but in painting vessels or other articles, this is not the practice.

Spun Glass.—The art of spinning glass consists in drawing it out into threads, when softened, by means of a wheel on which the thread is wound; the drawn out end of a glass rod has only to be attached to a revolving drum, while the rod, whence the thread proceeds, is held in the glass-blower's lamp, in order to obtain, in a few minutes, several yards of spun glass.

Glass from Cryolite.—An opaque glass, or, as it has been called by the manufacturers, "hot cast porcelain," has been introduced a few years ago in this country

by a company who purchased the monopoly from the Danish Government for exporting the mineral cryolite from Greenland. This species of glass is composed of ten pounds cryolite, twenty pounds white sand, and five pounds of oxide of zinc, which composition is well mixed and exposed in the furnace at the same high temperature as any other flint glass. We have seen a great variety of utensils cast in moulds of tiles, mantelpieces, statuary, mortars, evaporating dishes, pill tiles, funnels, ointment jars, and many other articles, capable of being cast, blown, or moulded, whilst in a melted state, and at a mere trifling cost, and to all appearance have the advantages over many other wares now in use. Mortars have stood the pounding and trituration better than a wedgewood mortar, and the evaporating dishes resisted the heat of both the sand and water baths, and all at about half the cost of ordinary porcelain. Lamp shades, and other fine parlor ornaments, finished in the best manner, and slabs of six feet long and four feet wide, without a fault, the writer saw in the sample room of the company. This glass or porcelain bids fair to supersede the French porcelain for toughness, strength and capability of standing sudden changes of temperature.

The manufactory has lately been suspended, and the causes of failure are unknown to the writer.

VII. *Soluble Glass.*—This glass has been fully explained in the first part of this book; the various modes of manufacture, and various kinds, and the various uses.

It is stated a simple silicate of potassa or soda, or a double silicate of these two bases. This body is solu-

ble in boiling water, without a residue, and scarcely affected by contact with cold water.

The soluble silicated alkali, also called water glass, may be obtained in various ways, as also explained before; at present, some large manufacturers employ powdered flints, which are dissolved in a caustic lye at a temperature of 300°. This water glass has found, lately, special application: 1. In protecting building stone from decay. 2. In hardening cements or mortar, so as to render them impermeable by water. And 3. For stereo-chromic painting. It is specially used as a protective varnish for pictures; as a fire and rot proof coating for all building materials of organic origin, such as timbers, &c., and inorganic matter.

The Chemical Properties of Glass.—Among the chemical properties of glass, there are some which merit an attentive examination: 1. The effect of the air or deoxydizing bodies. 2. That of water. 3. That of acids. 4. That of bases on glass.

Air or oxygen, cold or hot, provided they are dry, exercise no action on glasses. Not so with moist air; as has been stated above, the case is with the soluble glass.

It is evident that deoxydizing bodies may act with the aid of heat on glasses which contain oxides of iron or manganese, especially lead. When plumbous glasses are heated with charcoal, or in a current of hydrogen, they very readily undergo a remarkable alteration; the oxide of lead is reduced, and the metal being set free, communicates to the glass a blackish tint; this effect is so rapid, that we cannot operate on crystal glass at the enameler's lamp, without blackening it greatly.

The action of water is more or less on all glasses; it tends to decompose it into a soluble alkaline silicate, and an insoluble, earthy and alkaline silicate. The water, which is boiled for a long time in glass vessels, becomes alkaline and turbid by the portion of earthy and insoluble silicates; it is also very marked on crown, plate and window-glass.

It is well known that looking-glasses tarnish sometimes in the air, likewise optical instruments, owing to a deposit of a film of hygrometrical water. The windows of houses, offices or public buildings of an old date, often present a tarnished surface from the same cause stated; glass tubes, globes, retorts, watch-glasses, when exposed to moist air, exhibit the same phenomenon.

Action of Alkalies.—Concentrated solutions of all alkalies attack the glasses more powerfully than moist air.

Action of Acids.—The acids act on glasses with facility, particularly hydrofluoric acid, which acts in a peculiar manner; the other acids tend to decompose glass, by seizing on the bases, and setting the silica free. Among the bottle glass, many resist the action of wine, and are powerfully attacked by nitric, hydrochloric and sulphuric acids. A bottle glass, rich in alumina, is readily attacked by acids. Wines containing much bi-tartrate of potassa, so quickly attack glasses, that the alteration is perceptible in a few weeks. The action of hydrofluoric acid is such, that it transforms the silica of the glass into water and fluoride of silicium. It attacks glass rapidly, and this property has been traced to account to etch glass in a

gaseous or liquid state; the gaseous acid produces opaque traces, and the liquid acid transparent ones.

The physical characters of glass, in relation to heat, may be stated, that all glass is fusible, but the temperature for different kinds are different. Oxide of lead or a large amount of alkaline silicates imparts more ready fusibility. Borax produces a similar effect. Bottle glass, containing oxide of iron and alumina and less alkali, is more difficult of fusion than other kinds. When melted glass is cooled, it is perfectly flexible, and plastic through a wide range of temperature, before it becomes cooled to rigidity. The softer kinds, especially flint or borax glass, when heated, begin to be plastic before a red heat, the others at higher temperatures, and the plasticity of all increases up to perfect fusion. When in the plastic state two pieces will unite together as firmly as if they were melted together. Some glasses are more mobile than others when in fusion. When glass is much softened by heat, it may be readily drawn out into rods or tubes, or if passed around a revolving wheel, into minute flexible threads. From its perfect mobility when fused, it may be cast into large sheets, such as plate glass; from its plasticity below fusion, it may be moulded into any form by a few simple instruments, or by a mould of a given form; from the firm union of two plastic pieces very complex forms are attainable. Glass conducts heat so imperfectly, that the end of a rod heated to whiteness may be held with safety by the hand within an inch or two of the heated end; while this property is available for some uses, it is an inconvenience in other respects, which demands a remedy.

When a tumbler or other vessel of thick glass is cooled in the air, if it does not fly to pieces on cooling, it will readily do so by dropping in a grain of sand or minute angular piece of flint, while it may be struck a smart blow with a wooden mallet or other smooth body.

Prince Rupert's drops are pear-shaped pieces of glass, with a long thin stem, made by dropping melted glass into water. The bulb may be struck without injury; but if the smallest particle of the stem be broken off, the whole drop flies into powder with explosive noise and violence. These effects are due to the bad conducting power of glass, combined with the cohesive force of its particles. Glass expands when heated and contracts on cooling, but as its particles move more slowly in proportion as it approaches the cold, rigid state, the rate of cooling must be very slow to allow the particles to come uniformly close together. If suddenly cooled by dropping melted glass into water, the outside assumes the rigid and more contracted form, while the interior is still soft and expanded, from the bad conducting power of the glass. When thoroughly cooled, the interior must still retain the expanded state, so contrary to its cohesive force at common temperatures, and when the cohesion of the outer layer is in the least disturbed, as by a scratch or slight fracture, the whole of the cohesive force exerts its power to fracture the whole mass. These facts make it necessary to cool more slowly than can be done by the air, and give rise to the annealing process; the particles of the interior and exterior have then time to arrange themselves uniformly, according to their cohesive force at each

point of temperature, until they become perfectly rigid.

When transparent glass is maintained for some time at a high heat, but below fusion, it becomes opaque or translucent, fibrous in structure, harder, less fusible, and a better conductor of heat and electricity; it is so much harder as to scratch glass, give sparks with steel, and will bear sudden changes of temperature like porcelain. As an example, we have the famous devitrified glass as first prepared by Réaumur, and is more a crystaline glass, in distinction of ordinary amorphous glass; common bottle or window glass are most readily affected. Although a portion of alkali is sublimed, yet the change is not dependent on the loss nor on the presence of any accidental impurities; the alteration is wholly molecular, and consists in a re-arrangement of the particles in a crystaline form, where glass itself is entirely amorphous.

When crystaline glass is still more highly heated, it fuses, and then on cooling has the properties of amorphous glass, but requires a little higher heat for fusion, after each molecular change, which is due to loss of alkali.

The different kinds of glass have different degrees of hardness; bottle glass being the hardest, from the quantity of oxide of iron and alumina, and the smaller amount of alkali. Lead glass is softer and softer in proportion to the extent of oxide of lead; an excess of alkali imparts greater softness; the surface of the glass appears to be harder than the interior. Quartz, other hard minerals and a steel file scratch glass readily, and the diamond is generally employed, from its superior hardness, to cut the glass. The curved facets of

the diamond crystal present also curved edges, and while the point barely enters the glass, the curved edges or shoulders act like a wedge to split the glass. Glass is very elastic, as may be shown by any strip of window glass, but more strikingly by hollow balls suspended by strings. The ring or sound emitted by glass on being struck is dependent on its elasticity. A glass harmonicon consists of small strips of window glass of different sizes, suspended on two parallel strings, and may be graduated to any scale. Goblets of various sizes are sometimes employed in a similar manner, and are made to vibrate, by passing the moistened finger around their upper edges.

The discovery of glass is, without contradiction, one of the most important discoveries which accident or chemistry has rendered to civilization. Aside from its economical uses, it has exerted a singular influence on the progress of science. It is chiefly by this aid that astronomy has attained a perfection so wonderful. By the aid of the misroscope naturalists have been enabled to study a host of phenomena, which hitherto escaped their notice; the chemists could not perform any experiments without its use; and to glass we owe chiefly the present advanced state of the sciences, so fruitful in marvelous applications. The use of glass in our windows has introduced a degree of comfort into the meanest dwelling which previously did not appertain to the costliest palace. By means of the glass, the light is filtered from the wind, the rain and the cold; the one can be enjoyed without being inconvenienced by the other. With the improved methods of warming we can create an indoor climate, adapted to the desires and feelings of the dwellers. The em-

ployment of glass in many domestic articles of furniture contributes to cleanliness and health. A clean glass or decanter, water and other liquids, are physically tested by the glass. Glass, which is so extensively applied and used to so many purposes, has never been the subject of investigation in order to establish the theory of its combination.

The actual definition of glass is, that it is produced by the igneous fusion of silicious earth with certain alkaline earths or salts, or with metallic oxides. It is most probable that the name glass is derived from the latin word *glacies*, ice; its resemblance to it has probably suggested its title.

The art of blowing glass into bottles, making it into vases, tinging it to imitate precious stones, melting it in huge masses to make pillars, polishing it into mirrors, and staining it in part, was perfectly known in the most remote ages. Pliny's definition, that glass was discovered by some Phenician soda merchants, who having landed on the banks of the river Belus, served themselves with blocks of soda, which melting with the heat, transformed the sand on which they rested into glass, is very problematic, for it is well known what temperature is required for making glass. The Bible has reference to glass, and the Hebrews must have been acquainted with it while in Egypt. The Portland vase, which was composed of a deep azure glass, with figures of a delicate white opaque substance, raised in relief, was found in the tomb of Alexander Severus. It leaves no doubt that the art of glass making dates 3,500 years. The knowledge of glass making was transferred from Egypt to Greece, thence to Rome and modern Europe. The introduc-

tion into Italy was made by the Romans after their conquests; into Asia, at the time of Cicero. Glass beads and amulets, and the art of glass making was known in Britain before its invasion by the Romans. The glain neidyr, or Druidical glass rings, half as wide as our finger rings, but much thicker, have frequently been found; and a superstition regarding them existed, that they were produced by snakes joining their heads together and hissing; and success was thought to attend any one who was fortunate enough to find one of these snake stones; they were, evidently, beads of glass employed by the Druids, under the name of charms, to deceive the vulgar; they are, usually, of a green hue, but some of them are blue, and others variegated with wavy streaks of blue, red and white.

In Herculaneum, glass utensils have been found which date back to its destruction by the eruption of Mount Vesuvius, during the reign of Titus; two panes of glass were found in a window at Herculaneum. In the year 220, a manufactory of glass was established in Rome. In the year 674, window glass was introduced in England, but for several centuries the use of window glass was exclusively confined to buildings appropriated to religious purposes, while the windows of houses were filled with oiled paper and wooden lattices. The skill of the Venetians in glass making was especially remarkable in the excellence of their mirrors, while plates of polished metal were used at the toilet in other countries. France began to manufacture glass in the fourteenth century; but not until the year 1701, did success attend its manufacture, under the direction of D'Agincourt. In the year 1557

the manufacture of window glass was commenced in England, and Venetian workmen were employed by the duke of Buckingham in 1670 at Lambeth, London. The first painted glass was executed in England during the time of King John. The Reformation greatly impeded the progress of the art; it nearly disappeared during the reign of Queen Elizabeth. A glass painter, named William Price, is said to have discovered and kept secret the art of glass staining, and to produce a rich, clear, bright and transparent red.

In the United States the manufacture of glass dates as far back as 1790, by Robert Hews, a citizen of Boston, who erected his factory in New-Hampshire for making window glass; in 1800 another manufactory was established in Boston. The manufacture of flint glass originated in the Eastern States, and New-York and Pennsylvania followed it up, so that there are now at the present day 110 manufactories of flint and green glass, and 30 manufactories of window glass and lamp shades, consuming as follows:

Coal, over - - -	100,000	tons.
Sand, - - - -	10,000	"
Lead, - - - -	5,000	"
Soda ash, - - - -	6,000	"
Nitrate of soda, - -	3,000	"
Bicarbonate of soda, - -	1,000	"
Binoxide of manganese, -	200	"
Coloring materials for buttons and ladies' ornaments, such as zaffre, cobalt, oxides of copper, tin, antimony, chrome, uranium, &c., -	10	"
White arsenic, - -	20	"

The City of Pittsburgh contains the largest number of glass manufactories, on account of the cheapness of materials, such as coal and sand, which is at their command; there are no less than 65 establishments for producing window, flint and bottle glass, 20 bottle and vial, 23 window glass factories, and a number of glass factories whose exclusive production consists of lamp chimneys, and one-half of the glass manufactured in the United States. Pennsylvania claims two-thirds of the entire production of the United States. Pittsburgh consumes four millions of bushels of soft coal, and upwards of three thousand tons of soda ash annually; employs nearly five thousand hands, who receive three millions of dollars in wages. The improvements in making the glass are far advanced: when formerly 200 feet of glass were made by a blower at a single blowing, now there are 800 feet made; 8 x 10 was the largest size manufactured, now they are 40 x 70; formerly the thickness of the sheets averaged 18 to the inch, now they average 12, single strength; their present double strength is about one-eighth inch thick.

McCully & Co., manufacturers of green glass bottles, supply a proprietor of stomach bitters with 1,000 gross per month. There are a number of glass stainers constantly engaged there for steamboat furniture. The capital invested there is five millions of dollars.

In New-York State there are about 12 glass factories, in Massachusetts, 10.

The Specific Gravity of Different Kinds of Glass.

It may be of some importance to know the specific

gravity of glass, as it depends on the component parts. Alkaline calcareous glasses are the lightest; bottle glass comes next, then plumbiferous glasses, and the following table:

Bohemian glass,	spec. grav.,		2.396
Crown glass,	"		2.487
French plate glass,	"		2.488
Window glass,	"		2.642
Bottle glass,	"		2.732
Crystal, or common flint glass	"	from 2.9 to	3.255
Optical flint glass,	"	" 3.3 to	3.6
White flint glass,	"		3.000
Common green bottle glass,	"		2.715
St. Helen's green glass,	"		2.654
Crown glass,	"		2.520
Leith Crystal,	"		3.189
English Plate glass,	"		2.439

As regards crystal or flint glass, the density may suffice to give a pretty exact idea of its composition; it is, however, not so with the other kinds of glass, the difference of density of their constituents not being sufficiently marked; for the relations vary from so many causes, that to establish them in a positive manner it would be necessary to limit oneself to certain glasses, and it would therefore be best to have recourse to a chemical analysis, the result of which will always be more reliable.

TREATISE ON SOAP MAKING,

THE ART OF ITS MANUFACTURE, WITH AND WITHOUT THE AID OF SILICATES, AND DESCRIPTION OF ALL KINDS OF HARD, SOFT AND TOILET SOAPS; WITH TABLES OF THE COMPOSITION OF THE VARIOUS MANUFACTURERS, ETC., ETC., ETC.

By Dr. LEWIS FEUCHTWANGER.

Soap is a compound of salifiable bases with all fats and oils. When fats and oils undergo saponification by reaction with a salifiable base, the three principles contained in them, such as *stearin*, *margarin* and *olein*, are decomposed into oily acids peculiar to each, as discovered by Chevreul, a celebrated French chemist, in 1811, and called by him stearic, margaric and oleic acids, which unite with the base to form the soap, and a sweet principle, not saponifiable, called *glycerin*, which is set free; so that stearin is a stearate, margarin, a margarate, and olein an oleate of glycerin. Oils are mixtures of these three oily salts, and soaps are mixed stearates, margarates and oleates of various base.

Stearic acid is a firm white solid, like wax, fusible at 167°, greasy to the touch, pulverizable, soluble in alcohol, very soluble in ether, but insoluble in water; it is used as a substitute for wax in making candles. Margaric acid has the appearance of fat or hog's lard, which is fusible at 140°. Oleic acid is an oily liquid, insoluble in water, soluble in alcohol and ether,

lighter than water, crystalizable in needles at a temperature below 32°, and having a slight smell and pungent taste. Glycerin, the product of the decomposition, is a thick syrupy liquid, either colorless or of a slight amber color, without smell when pure, unctuous to the touch, and of a very sweet taste.

There are soluble and insoluble soaps; the soluble are combinations of the oily acids with soda, potassa and ammonia; the insoluble consist of the same acids, united with earth and metallic oxides. The soluble soaps are only used as detergents, and are properly named soaps, while the insoluble soaps are employed in medicine, such as, for example, the lead plaster, and liniments.

Soaps are mostly divided in hard or soft soaps; the consistency of the fixed alkaline soaps depends partly on the nature of the oil or fat, and partly on the alkali present. Soaps are harder the more stearate and margarate they contain, and softer when the oleate predominates. The alkalies have, likewise, a different effect upon their consistency; they are harder when formed with soda, and softer when containing potassa; the pure soaps are generally the hardest and least soluble, while oleate of potassa is the softest and most soluble. Mutton suet, beef tallow and hog's lard contain mostly stearine and margarine, but also olein; butters and other suets contain butyrine or butyric acid. A great many vegetable and animal substances contain either one or the other of the above or allied acids, and are converted into soaps by their combinations with any alkalies or alkaline earths, and receive thus the name from the substances they are originating; such as we have a cocoanut oil

soap, the product of cocoanut oil with lime; wax soap, made in the same manner.

Soap, and the *art* of manufacturing it, has been known to the ancients; the Romans followed it as a branch of industry, for they knew well how to use many vegetables possessing detergent properties, as also the virtues of alkalies, such as soda and kousa, a potash lye for similar purposes. Italy and Spain, in the eighth century, first established soap manufactories, and in the thirteenth century France followed up this trade; and Marseilles began to manufacture the oil soap, having learnt to extract the oil from olives, which were abundantly cultivated there, and to combine the same with the ashes of their algae, thrown out from the Mediterranean Sea. England, in the sixteenth century, followed up the French method, but in place of the olive oil, employed tallow, in connection with potashes and salt.

In later years, the English tallow chandler, or soap maker, conceived many improvements in his trade, by the introduction of rosin into his soap, which gave it many decided advantages. The great analytical chemist, Chevreul, among his many discoveries, studied the proximate principles, and made his investigations known in 1811, and produced quite a revolution in this domestic art; and from that period many new inventions and improvements have been introduced—both the machinery and application of heat; for no soap can be produced without the proper heat, whether by direct fire, as formerly, or by ordinary or superheated steam, as at present practiced; also, the various ingredients, like the caustic soda, where formerly barilla and soda ash were entirely used;

also, the time which was formerly wasted in producing soap, all of which form the improvements of the day in the manufacture of soap. The present soap maker operates systematically, uses his alkalimeter, in order to test the strength of his lye, and his thermometer, in order to hit the proper temperature when the heat required for saponification should be produced, and measures the exact time when to abstract the heat and when to cool the mixture.

Before proceeding to the manufacture of the various soaps, it is indispensable to state the different vehicles used in the process, the alkalies and lyes required for the saponification of fats, grease and oils. The *apparatus* used for boiling soaps consists in *brick kettles*, because they retain longest the heat during the operation; the *boiling pan*, the upper part of which, consisting of a wooden curb fastened into the rim of the boiler, is now in general use, for the reason, as ample space is required for the soap paste to froth upwards, when superheated steam is employed. They are only used in large factories, where from 100,000 to 130,000 pounds are weekly manufactured.

Cast iron kettles are found at present in small factories, also the sheet iron kettles, which have the preference over cast iron kettles. When the manufacture is conducted in open fire, common kettles must be so constructed as only the bottom undergoes the greatest heat, and not on the sides.

Superheated steam is now, however, the only apparatus in the manufacture of soaps, at the boiling point temperature, when the heat is introduced directly into the material, while ordinary steam would have to be condensed through a worm, and the condensed vapor

then to be discharged, and both time and fuel are much economized. Improvements are now continually made, both in machinery and materials. An apparatus, called Hubert's, where two boilers are employed instead of one, as usual, in connection with superheated steam, and when the lye and fat are introduced in both vats, steam in a superheated state is introduced, and injected into the entire mass.

The *steam jacket* is also a late improvement, for the purpose of mixing and boiling of the soap ingredients simultaneously.

The Alkalies.

Potassa, either the crude, or *pearl ashes*, are both, but mostly the latter, at present employed for certain soaps. The first is also called potash or caustic potassa, and contains but 60 per cent. absolute alkali, while pearl ashes contain 50 per cent. of pure alkali; the balance consists in sulphate and chloride potassium, phosphate and silicate of lime and other impurities, such as organic matter, free silex and lime, &c., &c. The pot and pearl ashes are used in producing soft soaps or fancy soaps, for the reason they do not produce such hard materials which the soda compounds do. In former times potash, mostly in caustic condition, was employed in soap making, and by the addition of salt, the soap was made hard; at present, however, potash or pearl ashes are mostly discarded in soap making.

Soda, in the form of caustic soda, soda ash and sal soda, are all now exclusively used in soap making. Barilla, which is the crude soda obtained from the incineration of the *kelp*, is still used by some old soap

makers in place of the caustic soda; there is also a natural soda, called urao, used in South America, which is purer than barilla, on an average containing but 25 per cent.; the same is, however, still in much use by the Spanish manufacturers, who bring the same in large quantities to England. The manufacture of soda ash, as obtained from salt, and transformation into crude carbonate of soda, under the name of *black ash*, its purification by lixiviation, evaporation and calcination, then assuming the name of *soda ash* or *white ash*, is the process pursued in England. Eighty per cent. carbonate of soda is the mercantile standard corresponding with the English per centage of 48 per cent.; 100 parts consist in 36 parts carbonate of soda, and 64 parts in water of crystalization.

Caustic soda, which is now exclusively used by soap makers, is generally purer and more caustic than the last mentioned alkali; it does not, however, bear much exposure, as it absorbs moisture from the atmosphere, and becomes fluid unless soon used, and is accompanied by a loss of material, but it is more certain and easier for operating on the materials.

Sal soda or soda crystals form a very important adjunct in soap making; they are mostly added after saponification has taken place, and for finishing by the operation called *filling* the soap. They are obtained by dissolving soda ash in ten times as much hot water, and allowing them to crystalize; they are used for softening the water and washing purposes. In nature the carbonate of soda is found in many countries as an efflorescence on the soil and in the beds of dried up lakes. The writer saw some years ago in Nevada large districts of land covered with a

white crust which was proved to be the carbonate of soda. In Carson valley miles of this alkali are spread over the surface.

Carbonate of soda has latterly been extracted from the Greenland mineral, called cryolite, which is largely exported from that country; it is extracted from cryolite by lixiviation, and carbonic acid passed through the solution, and the carbonate of soda left to crystalize. Cryolite, when mechanically cleaned and deprived of foreign substances, is employed in the manufacture of soap; it consists in 100 parts, of 13 alumina, 34 soda, and 54 fluorine, 10 by using the native minerals; it is used for filling in.

To test the strength of an Alkali.

In order to ascertain the quality and strength of the alkali used in the manufacture of soap, it will require a thorough chemical knowledge, which cannot be expected from a soap maker; but as it is of the highest importance to guard against imposition, and in the preparation of his lye, to learn the exact proportions for adding to the alkalies, it is necessary to give some short instruction on the subject.

The following points must be observed in the purchase of caustic soda, soda ash and potassa: 1. The water which is frequently left in the alkalies in order to increase the weight; 2. To estimate the amount of caustic and carbonated alkali. By heating 100 grains of the alkali over a gas lamp in an iron ladle for a short time, until all water is expelled, which can be ascertained by holding a cold glass plate for a moment over the ladle, when whatever vapor arises from

the heated material will be condensed on its surface; the net weight will indicate the amount of water in the above quantity.

As all alkalies are used in a caustic state, so it requires its estimation, which is done by treating fifty grains of commercial soda, finely ground, with half an ounce of strongest alcohol in a porcelain capsule; shake them well together, decant the liquid, and evaporate it quickly until it has become quite dry; weigh when cool, and ascertain the actual amount of caustic soda which the fifty grains at first used have lost; it is understood that you have tared the porcelain dish with the sample of soda, and that you deduct afterwards the weight of said dish, as soon as the operation is completed; now twenty grains loss would make the loss forty grains on one hundred grains of the sample. In order to estimate the amount of carbonated alkali, it is indispensable to ascertain first the quantity of either soda or potash, and then convert by calculation the value of the carbonated, which is done by dissolving fifty grains in a flask containing two ounces of water; then add from one hundred grains finely powdered oxalic acid to the alkaline solution so long, until a little strip of litmus paper becomes slightly reddened, the liquid being kept hot. The residue of the oxalic is then weighed, and the loss ascertained; if the loss is forty-three grains, then fifty-seven grains were consumed in the neutralization; it is known that 7.87 grains of oxalic acid are capable of saturating five grains of caustic soda, or seven grains of caustic potassa; five grains of caustic soda are equivalent to 6.62 grs. of carbonate of soda, and seven grains of caustic potassa are equivalent to 8.63 car-

bonate of potassa; 16.2 grains caustic soda are now equivalent to 21.5 grains of carbonate of soda, which, when doubled, gives the quotient of forty-three per cent. As we have found 10 per cent. water, 40 per cent. caustic soda, and 43 per cent. carbonate of soda, the balance of the one hundred grains soda ash must be seven grains as foreign substance.

For ascertaining the nature of foreign substances contained in a soda ash, such as a chloride or a sulphate, more chemical knowledge is required; but a few drops of nitrate of silver added to a clear solution of the suspected sample, which has been a little acidulated by nitric or sulphuric acid, will at once prove the presence of salt, which is chloride of sodium, or of a chloride of potassium, by a white flocky precipitate being formed; a sulphate may be detected by first neutralizing the solution of the suspected sample with a few drops of nitric, and then adding a few drops of chloride of barium, whereby a fine heavy white precipitate is formed.

The Alkalies are made into Lyes.

The soft waters, and those from rivers and springs, and free from organic matters, ought only to be used for the preparation of lyes.

Under the word lye, we understand the aqueous solution of caustic soda, or potassa, prepared from the common soda ash, or the crystals of soda, which are converted into the caustic state by means of lime-water, whereby the carbonic acid of the alkalies unite with the lime, forming insoluble carbonate of lime, which settles at the bottom; the whole operation is per-

formed in a large kettle containing hot water. The caustic state of the lye is ascertained by taking out a few drops, which must not effervesce with any acid; if found neutral, the lye is left to settle for twelve or fifteen hours before using it in the soap kettle; the lime required for the lye must be the fat lime, and twenty-four pounds of quick-lime are requisite for one hundred pounds of crystalized soda, while sixty pounds of fat lime are required for one hundred pounds of soda ash. If pearl ashes are intended for producing a lye, forty-eight pounds of fat lime are necessary for one hundred pounds of pearl ashes; an excess of lime does not produce an injury to the lye.

The strength of the lye must be ascertained by Baumé's hydrometer, which, however, only indicates the relative strength of the lye, with all impurities, yet is a sufficient guide for making it into soap. The following table exhibits the quantity of fused potassa and solid caustic soda in one hundred parts of lye, with their respective degrees, after Baumé's hydrometer:

Degrees.	Specific Gravity.	Potassa in 100.	Soda in 100.
40°	1.357	33.46	32.40
35°	1.299	29.34	28.16
30°	1.245	24.77	22.58
25°	1.196	20.30	17.71
20°	1.151	16.40	13.77
18°	1.134	14.38	12.
16°	1.117	12.29	10.26
14°	1.101	10.59	8.85
12°	1.085	9.20	7.69
10°	1.070	7.74	6.49
8°	1.055	6.25	5.46
6°	1.041	4.77	4.02
4°	1,027	3.21	2.92
2°	1.013	1.63	1.38
0°	1.000	—	—

In certain cases, it is requisite to transform stronger lyes into weaker of a definite degree of strength. Though, to effect this, much precision is needed; still, we think the reader will find little, if any difficulty, after perusing the annexed part, containing four tables for the reduction of strong lyes, published by Mr. Eugène Lormé, the excellent author of the work "Manuel complet du Savonnier."

The first column at the left of each table shows the quantity and the degree of the lye to be diluted.

The second indicates the quantity of water to be added to the lye.

The third gives the amount of the lye obtained by the admixture of both liquids; and

The fourth exhibits the areometric degree of the lye.

TABLE I.

Showing the different areometric degrees resulting from a mixture of 10 *gallons of soda lye, of* 36 *degrees Baumé, with quantities of water varying from* 10 *to* 60 *gallons.*

Number of gallons of Lye of 36 degrees.	Number of gallons of Water.	Number of gallons of obtained Lye.	Areometric degree of the Lye.
10	10	20	23
10	20	30	17
10	30	40	14
10	40	50	12
10	50	60	10
10	60	70	9
10	70	80	8
10	80	90	7¼
10	90	100	6¾
10 gallons of lye, of 36 degrees Baumé, weigh 112½ lbs.			

TABLE II.

Showing the different areometric degrees resulting from a mixture of 10 *lbs. of soda lye, of* 36 *degrees Baumé, with quantities of water varying from* 10 *to* 100 *lbs.*

Number of pounds of Lye of 36 degrees.	Number of pounds of Water to be employed.	Number of pounds of Lye obtained.	Areometric degree of the Lye.
10	10	20	21
10	20	30	14½
10	30	40	11½
10	40	50	10
10	50	60	9
10	60	70	8
10	70	80	6¼
10	80	90	4½
10	90	100	5 nearly.

8.8 gallons of lye, of 40 degrees Baumé, weigh 100 lbs.

TABLE III.

Showing the different areometric degrees resulting from a mixture of 10 *gallons of soda lye, of* 30 *degrees Baumé, with quantities of water varying from* 10 *to* 90 *gallons.*

Number of gallons of Lye of 30 degrees.	Number of gallons of Water to be employed.	Number of gallons of Lye obtained.	Areometric degree of the Lye.
10	10	20	19
10	20	30	nearly 14
10	30	40	11
10	40	50	9
10	50	60	8
10	60	70	7
10	70	80	6
10	80	90	5
10	90	100	4½

Remarks.—10 gallons of soda lye, of 30 degrees, weigh 100 lbs ; 75 gallons of this lye, and 25 gallons of water, give 100 gallons of lye of 25 degrees Baumé. There are 23¼ lbs. of caustic soda wanted for making 10 gallons of lye of 30 degrees Baumé.

TABLE IV.

Showing the different areometric degrees resulting from a mixture of 10 lbs. of soda lye, of 30 degrees Baumé, with quantities of water varying from 10 to 90 lbs.

Number of pounds of Lye of 30 degrees.	Number of pounds of Water to be employed.	Number of pounds of Lye obtained.	Areometric degree of the Lye.
10	10	20	17
10	20	30	12
10	30	40	9½
10	40	50	7½
10	50	60	6½
10	60	70	5½
10	70	80	5 or 5¼
10	80	90	4½
10	90	100	4
9.6 gallons of lye, of 30 degrees Baumé, weigh 100 pounds.			

The saponifiable oils and fats for the manufacture of all kinds of soaps are from the vegetable and animal kingdoms; the fats or fatty acids which, as already explained, consist of margaric, stearic and oleic acids, in combination with the oxide of glyceril in various proportions, we find the margarin principally in butters, and not drying oils; the stearin in the suets, and the olein forms the liquid portion of most animal and many vegetable fats; we also find the palmitin, which bears some resemblance to stearine, but is principally contained in palm oil, and which contains the acid in a free state, (not having any glycerin,) and for this reason possesses many advantages over other similar substances in the manufacture of soap. Fats contain also animal tissues, albumen, pigments, and frequently peculiar acids, and thereby producing peculiar odors,

of which organic chemistry gives hundreds of examples. Mutton fat and goose grease owe their peculiar strong odor to another acid, called *hircine.*

The vegetable fats or oils are numerous and of different consistencies; they are all lighter than water, of a specific gravity of 0.9 to 0.919, and all insoluble in cold and hot water, easily soluble in ether, and all possess a sweet taste; many of them undergo changes, some solidify, others thicken and become hard, but retain their brilliancy; they have therefore been classified with fluid and non-siccative oils. Linseed, hempseed and poppy oils belong to the first, and olive, palm, sweet, almond and cocoanut oils belong to the latter class.

Cocoanut oil, also called cocoanut butter, is found in a liquid state in the nut of some palm species in the southern or tropical hemispheres, such as Brazil, Ceylon and many Pacific States. It yields 60 per cent. of the fatty acid; it is white, sweet, and of the consistency of lard, mild taste and agreeable odor; it melts between 60° and 70° Fahr., and becomes easily rancid. It forms hard soaps, although it saponifies but slowly, and is therefore mixed with either tallow or palm oil, both of which are improved thereby, as it increases in emollient properties, and gives a brilliant whiteness to tallow soap.

Palm Oil.—Several varieties of palm trees yield the fruit containing the oil or butter. South America, Africa and the East Indies are the localities from where the extracted oil is brought to this country. The color of palm oil varies much, according to several circumstances, either of orange or even of violet.

Palm oil is prepared from the fruit of the palm

tree (*Clœis Guineensis*) as follows:—On its arrival at maturity, the fruit is plucked and thrown into a heap on the ground, where it is left for about a month. Fermentation is thus produced. When this is sufficiently advanced, the mass is thrown into large iron vats and boiled with water, the fruits being crushed in the hands of the laborers from time to time. After prolonged boiling, they are pounded in rude mortars formed from the trunks of trees, the kernels are removed, and the shells again boiled. The oil then floats on the surface of the liquid, and is collected with large wooden spoons.

Properties.—Palm oil is solid at the ordinary temperature of our climates; its color is a reddish yellow, and is esteemed in proportion to the deepness of its color. Its perfume resembles that of the iris or the violet. It melts at from 30° to 35° C., according to its age, but when freshly prepared its melting-point is lower. It is easily soluble in alcohol, and still more so in sulphide of carbon and ether. About 80,000 tons are annually manufactured. The oil mixes readily with water, which is frequently used to adulterate it; 50 per cent. may be added without fear of detection by the most practiced eye. In order to estimate the water contained in palm oil, a certain weight of it must be heated on a stove at 110° C.; desiccation will then ensue in a few hours. Unadulterated commercial palm oil contains from three to eight per cent. of moisture. A very superior quality of oil is obtained from the kernels of the palm, which are very large.

Ash.—Sand or earth is frequently mixed with palm oil during manufacture. To estimate this, calcine 50

grms. of oil in a porcelain capsule, and after the charcoal thus formed is burnt off, weigh the ash obtained. Palm oil sometimes contains from four to five per cent. of sand.

Impurities.—Sundry organic substances, such as the remains of palm leaves, etc., also occur. In order to estimate these, melt 100 grms. of oil in a capsule upon a water-bath, let it stand an hour, decant the limpid oil, and treat the precipitated impurities with sulphide of carbon, so as to dissolve the oil which adheres to the sides of the vessel. The impurities must be thrown on a filter, washed with sulphide of carbon, dried at 100°, and weighed. Some analysis are subjoined:

Loss in Palm Oil.

	I.	II.
Moisture,	8.25	3.12
Ash,	0.45	1.20
Organic impurities,	1.01	0.80
Total loss,	9.71	5.12

Palm oil produces a beautiful soap. It is mostly employed after having undergone a bleaching process, which is effected in the following manner: The yellow palm oil is heated in a wooden tank to 120° Fahr., chromic acid in its purity is then added, or five pounds red or bichromate of potassa dissolved in hot water is put in the tank under much agitation, and ten pounds chlorohydric (muriatic) acid and two and one-half pounds oil of vitriol, all of which is the proportion for 1,000 pounds palm oil to be bleached; after a

little while the process is completed and left to settle, the oil appears perfectly decolorized, and produces a soap of most brilliant whiteness, and is employed with tallow, about 20 per cent. to 100 of the latter, and is also a great deal used in the rosin soap, for the purpose of covering the flavor and brighten the color of the latter.

Olive Oil.—It is imported from the southern ports of Europe, and is obtained from the fruit of the olive tree. The virgin oil is the best oil obtained from fresh gathered fruit. Olive oil is often adulterated with cheaper and also animal oils; it makes the best soap. The well known Windsor and Marseilles soaps are produced with it.

Oil of Poppy.—The bruised seed of the poppy plant produces a fine oil; it remains liquid to zero, Fhr., is a drying oil. It is used in France, combined with tallow, for the imitation of Marseilles soap.

The following vegetable butter, such as the *galam*, a product of an African tree, of a reddish white color, and containing 82 per cent. stearine, and another butter from the African butter tree. The *stillingia* butter is imported from China; it is white and harder than tallow. The tree grows in the valley of Chusan.

The *mofurra* tallow from Madagascar, extracted from the kernels, which are of the size of a cocoa bean, is of yellowish color, and in odor similar to cocoa oil; it forms a brown soap with alkalies.

The Animal Fats.

They contain more stearine and margarine than the vegetable fats, and are distinguished by their color,

odor and consistency. There is much difference in the consistency of the animal fats. The fat or oil of whales is generally fluid, that of the carnivorous animals soft and rank flavored, and in the ruminants nearly scentless. Nor is the degree of firmness the same in all parts of the organism; the fat from the kidneys is generally harder and more compact than that in cellular tissues and bowels of animals, and the fat of the female is generally softer than that of the male. The color and odor of the fats have an influence in the manufacture of soap.

Beef Tallow.—This animal fat is well known; that rendered by steam is generally the whitest, has a yellowish tint, which may be removed by several washings in hot water; it is firm and brittle; its melting point is 111° Fahr., and becomes solid at 102° Fahr. The tallow from different countries are brought to market and command a different price, such as the Russian, South and North American.

Mutton Suet.—It is richer in stearine than beef tallow; when the fat is stale the smell is most disagreeable and nauseating. It is generally compact, firmer and whiter, and of less odor than beef tallow. It yields a beautiful white soap when saponified with soda lye, but may become too hard and brittle on account of its richness in stearine, and in the saponification about 20 per cent. lard oil is added.

Lard or Hog's Fat.—By freeing the adipose matter of the hog from the membranous, and melting it at moderate heat, so as to separate the fat from the cracklings, we obtain a fine lard, which has a granular appearance and can be pressed for oil without any further manipulation. That from hogs which have

been corn fed has the greatest consistency; it has, when fresh, a mild and agreeable taste. The consistency of butter and its melting point is at 81° Fahr.; consists of 62 per cent. liquid fat or olein, and 38 per cent. solid fat. It yields a fluid called lard oil when granulated and pressed at a low temperature. The pressed cake, consisting chiefly of stearine, is termed solar stearine, and used exclusively in the manufacture of candles; it forms a white, sweet and pure soap.

Horse Fat.—It is mostly extracted by steam from different parts of dead horses; it is from a white to brown color, and every horse yields about one hundred pounds. The soap from horse fat is white and firm, but has a very peculiar odor.

Bone Fat.—Fresh bones are used for extracting the fat, which is about 5 per cent.; it permeates the bones when kept for some time, and makes the extraction very difficult. It is recommended for purifying and deodorizing bone fat, by means of saltpetre and sulphuric acid, which are melted together; will produce a fat of a light yellow color.

Fish Oil.—The fat of several species of the whale fish, such as the cachelot, pot-fish, the Greenland whale, the Antarctic whale, different dolphin species, the norwall, the sea-pore, and several species of ribbon and mammifera belong to one class of whales, and they all have their specific names. The *white-fish* oil is an oil which flows out spontaneously from the fat heaped up in a reservoir. The name of *train oil* alludes to the *boiled fish oils*, which are of inferior quality. Fish oils are used as a burning fluid, for soft soaps, adulteration of other oils, and the manufacture of chamois leather.

Sperm Oil and Spermaceti.

In the head, and special cavities of the head of several sperm whales, especially of the pot-fish, or cachelot, and of some dolphins, there is a liquid fat, which, after the death of the animal, a large quantity of white, firm, tallow-like substance is separated; the liquid part is called sperm oil, and the solid spermaceti; the first is brought in commerce, bleached or unbleached, while the latter is more used for the manufacture of candles.

Oleic Acid.

This acid comes in trade under the name of *red oil*; it is a product from the manufacture of adamantine candles. Two kinds of red oil are brought into market, one formed by the process of distillation, which, owing to its disagreeable odor, is used for soft soap; the other, obtained by pressure, yields hard soaps, either alone or mixed with tallow or other fats. It is the product from stearine, called stearine cake; the first contains some oil vitriol, and has to be washed before using it.

Elaidic Acid.

If oleic acid is treated with hyponitric or nitrous acid, a pearly white crystaline substance is obtained, of the consistency of tallow, and is called elaidic acid. It is used with benefit in soap and candle manufacture.

The Manufacture of Soap.

For the purpose of the boiling of the soap materials, it is indispensable to produce a preliminary combination of fat and lye; and in order to form a union of the fats with the lye, the latter should be perfectly pure; and the same may, during this first operation, be of the same strength, or be commenced with a weak lye, then of middle strength, and finish with a strong one; the first may be from 10 to 15° B., and the second to begin with one of 7 to 10° B.; 15 to 18° B.; and lastly, 18 to 20° B.

In the manufacture of red oil soap, very strong lyes are employed, from 25 to 30° B. Usually, the fat is first put in the pan, and then the lye is added; but it is absolutely necessary that the lye be caustic and not carbonated, which will not decompose any fat, and therefore not unite.

By transforming one hundred pounds of fat into soap, fourteen pounds of caustic soda are necessary, generally more is employed; it is gradually and in small quantities added, as a large quantity of lye added at once will never act so energetically upon the fat as might first be supposed. When one-quarter of the lye is added in the beginning, it soon forms with the fat a milky liquid, which, in heating, gradually becomes clearer, producing a transparent soap solution, with intermingled fat drops; more lye is added under constant stirring, until the entire quantity of the same is consumed. This operation is called the *pasting*, for it displays a uniform clear mass, where neither lye nor fat can be distinguished. It shows, moreover, that the right proportion of fat and lye have been em-

ployed. When the spinning of the soap makes its appearance, that is, when the paste no longer drops from the stirring rod, but slides down in long threads, the operation is complete.

The second operation in the manufacture of soap is the salting process, to add dry salt, or the same in solution, for the reason that soap is insoluble in brine or strong caustic lyes, while weak lyes dissolve it; this operation is also called the "cutting up the pan." Upon this principle the *marine soap* is manufactured from the cocoanut oil soap, which is so serviceable for washing in salt water, as this soap possesses the remarkable property of being dissolved by a brine solution. The salting operation is effected by gradually stirring the paste with a stirring rod from below, upwards, through the brine or dry salt. Twelve to sixteen pounds of salt are necessary for one hundred pounds of fat, and after half the quantity of this salt is added, the soap ought to be boiled up for about ten minutes. The separation is perfect when the water is observed to run off from the curdy mass, and when on placing some of the soap in the palm of the hand and rubbing it with the thumb, it hardens into firm scales; or when the surface splits up into several fields, sepated from each other by deep furrows; the soap which was covered with froth and bubbles suddenly sinks, and the froth breaks up into roundish massive grains, distinctly separated from each other and from the saline solution. The mass should be left quiet for several hours, and the under lye (nigger) drawn off by the faucet.

The third operation is the clear boiling of the soap, so as to obtain hardness, consistency and complete

neutrality of the soap. The paste is boiled gently with tolerably strong lyes, in certain proportions, and boiled for eight hours; the lye is then drawn off, and a second boiling with lye is undertaken and drawn off again; a quick union of the alkali with the fat is thereby obtained; the process is terminated when large, regular and dry scales appear on the surface, which are easily pulverized by rubbing them in the palm of the hands; the soap should then be covered, left for some time, and eventually removed in the ladles.

Saponification by Pressure and Agitation.

The latest improvements in saponification consist either in pressure or agitation. The first is Rogers' patent process, where the agitation is performed at a low temperature, and not alone, as much time is saved to produce a thorough saponification, but also the bleaching of the soap is affected, so that inferior stock may be employed in the manufacture of soap. According to him, is the following: Into an iron tank the mixture is put, and then forced by means of a force-pump, and a pressure of about 400 pounds to the square inch; the mass is forced into a cylinder by steam; here it remains until complete saponification is effected; it is then drawn off in cooling frames and treated in the usual manner. This process has many advantages; the product is much firmer and more translucent soap, and the caustic soda may be substituted for carbonate of soda, even in smaller proportions.

Saponification by agitation is effected by an apparatus, consisting in a cylinder, six feet in diameter

and twelve feet long, and capable of working two and one-half tons of tallow with twenty gallons of lye, of 1.125 specific gravity, forcing 100 pounds tallow through the cylinder lengthwise; a shaft extends with radiated arms, to which an oscillating or rotary motion is communicated; agitation is kept up for three hours, the mass is then left undisturbed for a short time, and then removed into an open boiler, and completed in the ordinary way. The following processes were reported by the commissioner to the Paris Exposition in 1867:

The De Milly and Motard Process of Saponification.

After the lime soap is formed, it is decomposed by sulphuric acid, and the resulting fatty acids are cooled in shallow tin or copper pans, in rooms of about 60° Fahr., so as to allow of the proper crystalization of the solid acids. The next step is to press these acid cakes, which is first done in a cold press, then in a hot press, first suggested by Cambacérés, but successfully carried out by the horizontal presses invented by De Milly and Motard, and now universally employed in candle factories.

The difficulties, however, of these indefatigable manufacturers, were far from being overcome; the pans colored the fats with iron, the last trace of lime was not removed, and the candle made had a crystaline structure. By the alternate application of steam and dilute sulphuric acid, and white of egg and oxalic acid, they overcame the first difficulty. Various means were tried to prevent the crystaline structure,

commencing with the objectionable use of arsenious acid, then the more expensive one of wax, which also had a tendency to color the candle They at last triumphed over this difficulty, by cooling the acids to a temperature near their point of solidification before introducing them into the molds, that were first raised to the temperature of the cooling fats. During the cooling of the mass it is constantly agitated, and a pasty liquid is produced, which congeals in the molds without crystalization. Three years had now elapsed since the first establishment of their factory, the commercial results of which had been a failure. M. De Milly now came into the possession of the factory alone, his faith in its success remaining firm, and two years later, in June, 1836, he gave the perfecting touch to the successful manufacture of *star candles.* The wick has always been a source of great annoyance in the burning of the candles, for the small amount of mineral matter in the candle stuff would accumulate in the wick, and interfere with the free flowing of the melted fat. After numerous trials by saturating the wick with different substances, the required result was successfully accomplished, by impregnating the wick with a certain quantity of boracic acid, dissolved in water, containing one-thousandth of its weight of sulphuric acid. The boracic acid, as the combustion of the candle progressed, united with the lime and the ashes of the wick, forming a very fusible salt, which accumulated on the end of the wick, forming a small drop.

Sulphuric Acid Saponification.

This method was discovered by Chevreul in his original researches on fatty bodies; and in the patent taken out by him in conjunction with Gay Lussac, in 1825, this method is specified, but certain portions of the fats were so altered, as to discolor the product to such an extent as to render it of no use in practice. The acids, however, thus formed, could be distilled more or less perfectly, as first shown by Chevreul, and subsequently practically executed by Dubrunfaut. But the first idea of combining the two operations, viz., sulphuric acid saponification followed by distillation, is due to Coley Jones and Wilson, of England, subsequently perfected by Gwinne and Jones.

The process, as it is now carried out, may be summed up as follows: The fat is placed in large vessels, that may be of wood or masonry, lined with lead, and from six to fifteen per cent. of concentrated sulphuric acid is added; the mixture is then heated by a steam coil, to near the temperature of boiling water, and maintained at that temperature eighteen or twenty hours. Some, however, operate at a higher temperature, and consume less time in the reaction, with as much as thirty per cent. of sulphuric acid and agitation, decomposing batches of two hundred pounds in four minutes. The fat is decomposed with an alteration of part of the glycerine and part of the fat, sulphurous acid and carbonic acid being evolved. The black mass resulting from the action of the sulphuric acid is now thoroughly washed by boiling water, until all the fatty acids are freed completely from sulphuric acid. The fatty acids are now introduced into large

cast-iron stills, capable of holding over one ton of these acids. The stills are heated from below, so as to bring the contents to the temperature of 260° C., when a jet of superheated steam of 350° to 380° C. is made to traverse the charge, and in about twelve hours the matter is distilled over, leaving behind a pitchy substance, which may be used in the manufacture of gas, or for coating roofs, and other purposes in the arts. The fatty acids, when distilled, may be cooled in pans, and submitted to the cold and hot pressure; for some purposes it is submitted only to the cold pressure, and in England is much used without any pressure at all, when palm oil has been the fat acted upon.

Saponification by Sulphuric Acid without Distillation.

Fats saponified by sulphuric acid by the ordinary method, contain more or less tarry matter, arising from the decomposition of the fats, causing more or less loss in the raw material.

M. De Milly undertook a series of experiments, by which he finally showed that fats could be saponified by sulphuric acid without the formation of tarry matter. This point being established, he further showed that the fatty acids obtained without the formation of tarry matter, were identical with the fatty acids formed by the lime saponification. These he submitted to cold and hot pressure under special conditions, and obtained cakes of candle stuff most beautifully white. As to the oleic acid, it is of a dark color, but in no way decomposed; it makes a fine brown soap, or it can be distilled and made white.

M. Balard, in a report on this process, expresses himself in the following terms:

"In the establishment of M. De Milly, the fat is melted and heated to 120° C.; it is then allowed to flow from its reservoir and mix with a stream of strong sulphuric acid, in the proportion of six per cent. of the latter. The mixture is rendered perfect by means of agitation. The action takes place immediately, and is arrested in two or three minutes, by allowing the mixture to flow into boiling water, when the sulphuric acid and unaltered glycerine enters into solution, and the fatty acids float on the surface, being of a dark color. But, contrary to what takes place in the ordinary method of saponification by sulphuric acid, the coloring matter is completely soluble in the liquid fat acid, so that by cold and hot compression, the solid fat acids are obtained perfectly white, ready to be molded into candles. The entire operation can be accomplished in one hour."

The Manufacture of Family Soaps.

There are generally four different kinds of soap brought into market, which consist in—1. Hard; 2. Soft; 3. Toilet or perfumed; and 4. Silicated soaps.

The *hard soaps* are invariably made from soda; they are divided in boiled soaps and those made in the cold way. Another division is made among hard soaps, such as *grained*, or those where the separation of the underlye (nigger) has been made, as has been already noticed under the head of cutting up the pan, and in filled soaps, or such where the whole contents of the boiling pan are kept and crutched together,

and sold as soap. The more solid constituents a fat contains, the harder is the soap, and the more oleine, the softer. In mixing the fats in different proportions, soaps of every consistency are obtained. Weak and middling strong lyes will produce a light soap, while lyes of 25° to 30° B. will produce a soap heavier than water. Glauber salt, not over one per cent., is sometimes added in order to prevent too great solubility of the soap in washing; it is called then

Electric Soap.—Rosin, in the proportion of one-third or one-fourth of the fat employed, is frequently used, and the soap is called Rogers' soap. Twelve and one-half pounds of solid caustic soda are usually consumed for 100 pounds of fat, for its conversion into soap. A new soap, composed of the rosin soap, to which is incorporated a mixture of spirits of turpentine, ammonia and pearl ashes, and by other manufacturers a quantity of flour and benzine are added to the above mixture, and all crutched in the rosin soap.

Tallow Soaps.

The most ancient, and at the same time the most important, is the tallow soap; it is cheap, and called for by everybody, both in the household and the manufactory. The following is the mode pursued by the most experienced soap makers: To 1,000 pounds fat, which is melted at a slow heat, from 70 to 80 gallons lye, standing 10 to 12° B., are added and kept stirring under a gentle fire for several hours. Should a part of the fat separate from the mass, which is often the case, an oily liquid will be observed floating on the top; it requires then the addition of 35 to 40 gallons

more lye, of 15 to 18° B., whereby the whole contents will form quickly a homogeneous mass of a grayish white color; a gentle boiling must be kept up for several hours, and adding every hour six to seven gallons of lye of 20° B., when the paste assumes the proper consistency; this operation requires ten to twelve hours. And then the second operation has also been described under the salting process, where the ingredients have to be well stirred while adding the salt, and after separation has taken place, several hours are necessary for settling; and then to draw off the colored underlye, 90 gallons of lye of 25° should then be added, and the heat increased, so as to preserve the soap from bubbling. The whole mass is then boiled from ten to twelve hours, adding every hour five gallons lye of 25° B.; but after boiling four to five hours, the operation is perfected, and the fire withdrawn, left quiet for an hour, and the underlye is drawn off; the soap will then separate from the lye and rise to the top; after five to six hours, while yet liquid, it is put in pails or ladles, into the frames, taking much care that no lye is mixed with it. In the frames, which are either of wood or iron, it must be well stirred and crutched for some time. In order to cover the not agreeable smell of the tallow, two ounces of oil of mirbane should be added to every 100 pounds of soap; after seven to eight days it may be cut. 100 pounds of tallow will yield from 165 to 170 pounds of soap.

Tallow Rosin Soaps.

It is well ascertained that the addition of rosin, to a certain amount, will make the soap more detergent,

more soluble and cheaper; it does form a soap with the tallow; 15 per cent. rosin, and 85 per cent. tallow, make a good proportion; any excess will depreciate the soap in firmness and quality; the soap will become clammy if 33 per cent. are used; it will be too soft; but twelve gallons of lye of 30° B. may be used for every 100 pounds of rosin; it may be melted with the fat in the commencement of the boiling for soap, although it is more expedient to make first the tallow soap, and then mix the rosin soap, compounded in another kettle, to the first. Both soaps have then to be well stirred and beaten thoroughly for half an hour, and then passed through a sieve, before they are filled into the frames, where they are also well stirred and crutched. By adding to the saponified tallow some palm oil, the appearance of the soap will be thereby much improved.

A practical soap maker stated to the writer a short time ago, that he uses ten pounds of tallow, nine pounds of rosin, and five pounds of filling of sal soda and starch, which he adds after the saponification has taken place.

Cocoanut Oil Soap.

This oil, as already mentioned, acts differently from any other fats, in combination with which weak lyes produce a milky mixture. A lye of 27°, when cold, will saponify 100 pounds cocoanut oil, and produce 200 pounds soap. The process is very simple: the oil and lye are put together, and the heat is applied; after stirring for one or two hours, the paste is seen thickening gradually, and the heat is moderated while

the stirring is continued. After a while the paste becomes transformed into a white semi-solid mass, which forms the soap, and this has to be filled immediately into the frames, as solidification quickly ensues. Equal parts of tallow and cocoanut oil, or only cocoanut and palm oil, (bleached,) yield a very fine soap; also, 90 to 95 per cent. cocoanut oil with 5 to 10 per cent. natural palm oil, yield a fine soap; the saponification takes place of fats and cocoanut oil, if not in too large a proportion. It is to be remarked, that the mixture of cocoanut oil and other fats and lye need not be separated with brine.

Castile or Spanish Soap.

This is also a hard soap, a pure olive oil soda soap, and is imported here under two principal varieties, the white and the marbled. The white Castile soap is of a pale grayish white color, does not give an oily stain on paper, devoid of rancid odor or strong alkaline qualities, entirely soluble in water and alcohol. It becomes dry by exposure to the air without displaying any efflorescence; it contains 21 per cent. water.

The marbled Castile soap is harder, more alkaline and more constant in its composition, and contains but 14 per cent. water; it is, therefore, stronger than the first, and more economical. The process of marbling, which is explained on page 324, is by producing veins of ferruginous matter, makes the marbled soap somewhat impurer. This soap is mostly used in medicine, for the manufacture of opodeldoc, suppositories and in pills, and in great demand for

family use; particularly the genuine soap, which is brought from Marseilles in small boxes and bars, weighing from three to four pounds each. It is much imitated in Paris and London, and instead of olive oil, tallow is mixed with it, which can be detected by analysis.

Soft Soaps.

The difference between potash and soda soaps consists in the difference of consistency; the one is hard, and the latter soft, while the first is clearer and purer, the other is darker, smeary and much cheaper. Fish oils and red oils are mostly employed for soft soaps, therefore much cheaper.

Saponification is commenced with a lye of 9 to 11° B., and the contents of the kettle kept boiling until the paste becomes of sufficient consistency to draw threads, as it were, out of a streaky substance. It then undergoes the process of clear boiling, for which purpose lye of 25° B. should be used. It must be stirred constantly; but when the paste does not sink any more, (first it ascends,) boils quietly and shows the formation of scales, it may be considered complete. The barrels should be immediately filled, in which it is to be offered to the trade. Hempseed oil is used in Prussia for soft soap, which is quite green; but whale oil is principally employed. Many other oils, such as linseed oil, poppy oil, rapeseed, colza and cotton seed, are all used for a smear soap; and in order to give the desired color of soft soap, various colors are added to it, such as indigo solution, with lime, &c.

Palm Oil Soaps.

Palm oil is rarely used exclusively as a soap stock; it is generally employed with rosin for obtaining a yellow soap. White soap from the bleached palm oil, combined with the cocoanut oil, is in great demand, say ten per cent. of the latter to ninety per cent. of palm oil, as with filled soaps. Tallow and palm oil, with a small quantity of rosin and cocoanut oil, produce a fine and hard soap.

The following receipts are known to the principal soap manufacturers:

Palm oil,	300 lbs.	Palm oil,	450 lbs.
Tallow,	200 "	Cocoanut oil,	50 "
Rosin,	20 "		
		Hog's lard,	550 "
Tallow,	500 "	Palm oil,	150 "
Palm oil,	300 "	Cocoanut oil,	50 "
Rosin,	200 "	Rosin,	50 "

Palm oil may be made into soap in the same manner as tallow, and if rosin is to be incorporated, it is best to produce first the combination of the rosin with the lye, and then mix the same with the finished palm oil soap. Palm soap becomes bleached when exposed to the light.

The Silica Soaps.

All soaps, whether hard or soft, and whether for domestic use or family soap, or for manufacturing purposes, bear safely an admixture of silicate of soda,

to the extent of 20 to 25 per cent. (35° B.) to the ready prepared cold soap; but it requires that the silicate be perfectly neutral, for if there is the least trace of fatty acid, silica will be precipitated, and the alkali will effloresce from the soap after a short time. The dissolved silica, either the silicate of soda or potassa, of about 1.4 specific gravity, is generally added while the soda soap is still hot, but is previously transferred from the cauldron into a tub or pan, called the mixing vessel, capable of containing about 1,400 weight of soap, and the silicate is to be added in such proportions as to yield the particular quality of soap desired to be produced; the mixture is then well agitated by means of crutches or paddles. The soap and the viscous solution should each be at such a degree of heat, that the mixture, when formed, may be at a temperature of 160°, and the agitation is to be continued until the temperature is reduced 10°, or 150°. The mixture is then transferred to the cooling frames, and agitated therein by means of crutches, until it becomes of such consistence as to render its continuance no longer practicable. If a more rapid agitation could be applied, the soap produced is a more perfect mixture, and more uniform. The solution of silicate of soda at 35° B. is well for an addition to any soap. The curd or white soap, the yellow or rosin soap, the palm and olive soaps, may all be treated with the addition of 20 to 25 per cent. of soluble glass, standing from 25° to 35° B., and the manipulator will succeed in producing a good detergent soap, which will not crust after a short time if the following rule is observed:

Do not add the soluble glass until after the saponi-

fication is complete, and before the soap is cold. Use the silicate of soda hot, and as neutral as possible, and crutch it with the ready made soap in small portions, and do not use more than 20 to 25 per cent. of the silicate to the soap, and continue the operation of crutching for several hours. In order to be able to use the silicate of soda in a neutral state, for the common soluble glass is more or less alkaline, it is best to add two pounds of hydrochloric acid to each twenty gallons of the soluble glass solution, standing 30° to 35° B., and while hot keep the acid agitating for an hour or so, when the same will become neutral and suitable to be mixed with the soap in the mixing vessel.

The common silica soap in trade consists of

90	pounds	salt,
15	"	cocoanut oil,
15	"	caustic lye,
50	"	silicate of soda.

The soluble glass may as well be used in soft soaps in the same manner as described for hard soaps. The mixed silicated soaps may be obtained of any requisite degree of hardness, by the greater or less concentration of the solution of soluble glass. The compound soaps produced by this process are possessed of valuable detergent properties, independently of the real soap contained in them. Many varieties of soap are known in the trade under the name of silicated soaps. Silica, silex, sand and pumice soaps, even when the soap is mixed or adulterated with white china clay, talc, soapstone, and other materials ; those soaps are offered under the name of silica.

In the preparation of sand soaps, the finely sifted sand or flint is added to ordinary white soap, and thoroughly incorporated with it, while in the pasty condition, from eight to ten per cent., and as soon as the mass has cooled, it is taken from the frame and cut into tablets or molded into balls.

Mottled or Marble Soap.

In the manufacture of this variety of soap, the same kinds of materials are used as for white soap, and its different appearance arises from the different mode of treatment of the soap, after the completion of saponification. It has already been observed, that even after the complete formation of the soap, that is, when the whole of the oil or fat used is decomposed, and the oily acids have entered into combination with alkali, the soap still requires further treatment before it is brought to market; the immovable globules have to be brought into a homogeneous mass, which is effected by the process termed fitting, which consists in the fusion of the contents of the boiling cauldron in a weak lye or in water, and afterwards boiling the whole for a longer or shorter period, so as to break the froth and favor evaporation. During this process in making white or curd soap, the more or less colored impurities of the materials, termed nigger, fall to the bottom; but in making mottled soap, the mixture is left in a thick or viscid state, so that the impurities cannot subside, and is transposed to the frames in this condition.

To produce a good marbled soap, it is necessary that the latter operation be very carefully conducted,

for if too great a quantity of liquid be added, or if the mixture of soap and water or weak lye cools too slowly, all the coloring matter falls to the bottom, leaving the upper stratum of soap perfectly white, while, on the other hand, if it becomes too quickly cold, the soap remains in the granular condition. The lower veins in mottled soap appear to be due to the presence of exceedingly minute traces of sulphide of iron, derived from the last service of lye, in which it exists in solution as a double sulphide of sodium and iron. At Marseilles and other places where olive oil is used in making soap, a quantity of sulphate of iron is added, whereby the mottling is produced; about eighteen ounces of copperas to 450 pounds of oil, which is added, first mixed with weak lye, are poured in during the coction of the soap, and before it has acquired too much consistence. When the soap is ladled out of the boiler, it is of a uniform slate tint, but as it becomes cool, the metallic portion separates into nodules, and by the trickling of the excess of lye through the mass, they assume those forms to which the term *mottled* is applied. According to the tint of the sulphate of iron, a lighter or darker hue appears on the surface of the soap.

Toilet Soaps.

The great variety of soaps thus designated are usually prepared by remelting and clarifying white or curd soap, and adding various perfumes, colors, etc., all of which is more the province of the perfumer than of the soap maker. The most convenient method of preparing soaps for the toilet is by the cold process. The following method is pursued :

First, the fat is melted in a well cleaned iron or copper kettle at a low temperature; it is filtered then through fine linen or muslin into another kettle, when it is boiled with one-third of water for ten minutes, and then strained off. Some add for 100 pounds of fat, six ounces salt and three ounces fine pulverized alum; they let it remain quiet for some hours, until it becomes what is called *figging.* To the fat, which must not be warmer than 104° Fah., the lye is gradually added. In the soaps made *after the cold way*, a very strong lye is used, say 36° B., and for a certain quantity of fat just half is employed, say for eighty pounds fat, forty pounds of lye. The lye must be entirely clear and colorless, but it is not necessary that it be heated previously, when it has been kept in a warm room. For stirring it, a broad paddle of box-wood must be used, having sharp edges at the lower end, and rounded at its upper end, so that it may be easily handled. The necessary coloring matter and perfumery should be added as soon as a ring drawn with the spatula can be recognised. The paste is now run into frames previously lined with linen; each frame should be entirely filled with the mass, and well closed with the linen and wooden cover, and left then for twelve hours, by which time saponification will have been effected; the mass, which was nearly cold when run into the frames, has undergone a spontaneous reaction, raising the temperature over 175° Fah. The different constituent principles are now combined; the soap produced is of a quality resembling that of boiled soaps. After twelve hours the soap is taken out, and cut and dried; and for making it a little softer one-tenth of

potash lye is added to the soda lye, for the purpose of increasing the solubility, and consequently the quality of the soap; for when no potassa is added, these soaps are generally hard; 100 pounds of fat will yield about 150 pounds of soap.

KURTEN'S TABLE,

Showing the composition and yield of Soap by the Cold Process, from Concentrated Lye, and mixtures of Cocoa Oil with Palm Oil, Lard and Tallow.

KINDS OF SOAP.	Tallow.	Cocoanut Oil.	Palm Oil.	Lard.	Lye.	Degrees.	Salt Water.	Degrees.	Potash.	Degrees.	Product.
Cocoanut Oil, No. 1, ...	..	100	..	..	56	36	..	..	..	..	153
Paris Toilette, (round,).....	20	30	..	8	31	36	..	..	5	36	87
" " "	..	25	..	75	50–52	36	..	..	..	..	150
Windsor, (square,).........	66	34	..	..	77	30	..	..	13	30	185
Shaving, No. 1,...........	66	34	..	..	.....	..	..	..	..	..	...
		or	..	..	120	27	..	..	..	..	214
	33	34	33	..	.....	..	..	..	..	..	...
Shaving, No. 2,...........	33	34	33	..	120	27	12	12	..	..	226
Washing, No. 1,..........	60	40	..	..	.....	..	..	..	..	..	...
		or	..	..	125	27	25	12	..	..	244
	30	40	30	..	.....	..	..	..	..	..	...
Washing, No. 2,..........	40	60	..	..	....	..	..	..	..	..	...
		or	..	..	135	27	50	15	..	..	278
	..	60	40	..	.....	..	..	..	..	..	...
Ordinary Cocoanut Oil, ...	..	100	..	..	.....	..	..	..	..	..	...
		or			.....						
	10	90	..	..	225	21	75	12	..	..	400
		or									
	..	90	10	..	.....	..	..	..	..	..	...

The marbling of these soaps is produced by rubbing up the coloring material, such as vermilion, smalts, or ultramarine, with a little olive oil or soap, a small portion of which being taken on a pallet knife, is pushed through the melted mass. Thus the pink color of rose soap is produced by vermilion; blue by means of ultramarine, and brown by the addition of the various

kinds of ochres and umbers. Generally speaking, the colors are varied much, particularly since the aniline colors are so much used. The violet is obtained from fuchsine dissolved in glycerine; green color, the real chrome green is used; chrome red is also employed for a red coloring, and caromel or sugar coloring for producing a good brown color. The lemon and orange yellow, with which we often find the German oval cakes of fancy or toilet soaps colored, is the sulphide of cadmium, known under the name of cadmium yellow, which is not dissolved in the soap, but merely suspended by very careful mixing, for it is rubbed up with oil, and added to the soap under constant stirring; it requires but a very small quantity to produce a lively color, and neither sun nor age affect the color. The cakes or tablets are formed by placing a soft mass of soap in a mould fixed in a lever press; the mould consists of a top and bottom die, fitting into a loose ring; by a sudden pressure the shapeless mass assumes the form of the ring, and is embossed on the top and bottom.

Naples Soap.

This highly esteemed shaving soap, always imported from Italy, is said to be produced by saponifying mutton suet with lime, and then separating the fatty acids from the soap so formed by means of a mineral acid. These fatty acids are afterwards combined with caustic potassa, by ebullition in the usual way.

Transparent Soaps.

They are prepared by dissolving well dried soaps in alcohol. Those made of olive oil will not become

transparent with alcohol, but become opaque. Good suet and rosin, and tallow soaps, are best suited for a transparent soap. The mode of proceeding is to cut into very thin ribbons, by means of a cutting mill or knife, and left to dry in the air or sun for some time, until properly dry; it is then pulverized, and then dissolved in strong boiling alcohol, say 80 per cent.; when the soap is liquid, the colors and perfumes are added to it. Three and a half gallons alcohol, of spec. grav. 0.849, is suitable for fifty pounds soap. A still heated by steam or hot water is generally used for this purpose, in order to save the alcohol, which will amount to five pints, will pass over from the employed three and a half gallons into the coolers of the still. The thick liquid in the still is turned out into moulds arranged for them, either balls or square moulds; but their capacity should be one-third larger than the size of the forms intended, thus allowing for the shrinking of the soap material. The soap becomes dry after a few days, and when of a dull appearance is turned off with a round knife, and a neat surface produced by rubbing it with a fine linen, saturated in alcohol.

Perfuming Soaps.

When the paste or soap is already in the frames, the process of perfuming is performed, and the same must be nearly cold, else the essential oils would be volatilized; it is, therefore, best to mix the colors and perfumes together with some alcohol or glycerine, and stir them well up in the paste. In France, where the finest soaps are manufactured in the cold state, very highly perfumed soaps are prepared. Although the

process is very simple, still, their mechanical ingenuity makes their soaps excelsior.

Formulæ for some well known soaps:

Windsor Soap.

1. (White.) The best English Windsor soap is produced from a mixture of

1 pound olive oil,
8 " tallow,

both saponified with caustic soda lye, and scented after the removal from the boiler. Curd soap, well scented, is sold generally for Windsor soap, being flavored while semi-liquid with oil caraway, and a very small quantity of oils of bergamot, lavender or origanum are added, say about one and a half pounds of the oils to every hundred weight.

2. Brown Windsor soap. It is the same as the white, only colored by caromel, and sometimes with umber or ochre.

Honey Soap.

The finest rosin soap, colored by palm oil, or palm oil soap, and scented with rose geranium and a little oil of bergamot or verbena. Some honey soap has the following composition:

1 pound olive oil soap,
1 " palm oil soap,
3 " white curd soap,

colored by a little palm oil or annatto, and scented with various fine essential oils of one and a half pounds to every hundred weight.

Musk Soap.

The base of this soap is a good suet or tallow soap, scented with tincture of musk and a little oils bergamot, cinnamon and cloves, and colored by caromel. Ambergris soap is made in the same way as musk soap.

Glycerine Soap.

Any hard soap in which three or four per cent. of glycerine has been intimately incorporated while in the paste, will represent this soap. It is colored of a red or rose color, or orange-yellow; oil geranium and oil cassia, with a little essential oil of bitter almonds, are the favorite perfumes.

Struve, of Leipsic, prepares a glycerine soap in the following manner: 40 pounds tallow, 40 pounds lard, 20 pounds cocoanut oil, are saponified with 45 pounds soda lye and five pounds potash lye, of 40° B., and the soap is to be made in the cold way. To the paste are then added:

6 pounds pure glycerine,
½ ounce oil bergamot,
½ " " portugal,
5 ounces oil bitter almonds,
3 " " vitiver.

Almond Soap.

The bitter almond soap is made from the white curd soap, with or without the addition of 1-7 of its weight of olive oil soap, scented with the essential oil of almonds, or oil of mirbane, in the proportion of

about one ounce to each five pounds; a little oil cassia improves it.

Violet Soap.

This toilet soap is the white curd soap, scented with orris root, and colored with litmus tincture; also by melting

3 pounds white curd soap,
1 pound olive oil soap,
3 pounds palm oil soap; and the whole scented with orris root.

Bouquet Soap.

Olive soap, $2\frac{1}{2}$ pounds,
White curd soap, $17\frac{1}{2}$ pounds,
Oil bergamot, 1 ounce,
Oils cassia, cloves, sassafras and thyme, each $1\frac{1}{2}$ drachms.
Oil neroli, or English lavender, 1 drachm,
Levigated brown ochre, 2 ounces.

Another bouquet soap is made from

20 pounds curd soap,
$2\frac{1}{2}$ ounces oil bergamot,
And oils cloves, neroli, sassafras and thyme, $\frac{1}{2}$ drachm,
And colored with $2\frac{1}{2}$ ounces brown ochre.

Rose Soap.

Palm oil soap in shavings,	3 pounds.
White curd soap "	2 "
Soft water,	4 ounces.

Melt in a bright copper pan and water-bath, and add $\frac{1}{4}$ ounce of vermilion, or perfume with

$\frac{1}{4}$ ounce otto rose,
$1\frac{1}{2}$ drachms oil bergamot,
$\frac{1}{2}$ " rose geranium,
$\frac{3}{4}$ " of oils cinnamon and cloves.

Another rose soap is made from 20 pounds curd soap and the variety of oils.

Cinnamon Soap.

It is a mixture of tallow and oil soap. Take

6 pounds white curd soap,
$3\frac{1}{2}$ " palm oil soap,
1 pound cocoanut oil,
$1\frac{1}{2}$ ounces oil cinnamon,
$\frac{1}{4}$ ounce oils bergamot and sassafras, each,
1 drachm oil English lavender,
$\frac{1}{4}$ " levigated ochre.

Lavender Soap.

It is Windsor soap scented with essential oil of lavender, and essence of musk and ambergris.

Orange Flower Soap,

Like rose soap, flavored with oil neroli, and ambergris, and portugal.

Military Shaving Soap.

To the white olive oil soap is added the bayberry wax, and scented with oils caraway and cassia.

Cream Soap and Shaving Paste.

These preparations are excellent for shaving; they are composed of

White soft soap,	4 ounces.
Finest honey soap,	2 "
Olive oil,	1 "
Water,	2 tablespoonsful.
Carbonate soda,	1 drachm.

Melt them together and form a paste, adding a little proof spirit, and scent at will; by adding about 1 drachm spermaceti the paste becomes more soft; it makes a lather with cold water.

Cream Pearl Soap.

Take lard potash soap, or white soft soap, rub it up in a marble mortar, so as to become a uniform mass, or pearly, and scent it with oil almonds and cassia.

Shaving Essence.

Take white hard soap,	$\frac{1}{4}$ pound,
" pure spirits,	1 pint,
" water,	4 ounces,

and perfume at will. Let the mixture stand in a water-bath for a few days, occasionally agitating it, until it is completely dissolved; draw off the clear liquid, and perfume it to suit.

The Commercial Value of Soaps.

Since we distinguish soft soaps (potash soaps) from hard soaps, (soda soaps,) and filled soaps from grain soaps, it is necessary to ascertain the intrinsic value of any soap, according to its purity. In the first

place, we recognise two main varieties, or groups: first, the rosin soaps, and second, the fat or oil soaps. Among the latter are the more important, such as tallow soaps, palm oil, cocoanut and olive oil soaps. In addition to these, however, there are many mixtures of fatty substances in combination with alkalies, known as soaps. In good soaps there is a definite proportion between the water, the alkaline base, and the fatty acids; there should be no excess, either of the base or of the constituents of the fat, at the same time it must be free from salt or an excess of water, which is but an adulteration, like other substances known to be mixed into soaps, like sal soda, alum, salt, bone ash, glauber salt, or clay. A good soap is easily soluble in alcohol, scarcely leaving one per cent. of solid residue, and forms a gelatinous liquid in boiling water.

A hard soap should not contain more than 25 per cent. of water, of rosin not more than 40 per cent., and of soft soap, not more than 52 per cent. For cocoanut oil soaps, a larger amount of water than 52 per cent. may be allowed. In the yellow soap, a part of the fat is replaced correctly by 10 to 15 per cent. of rosin. All these proportions are reliable, and if increased or replaced by other substances, the quality of the soap is diminished, although some soap makers think that an excess of alkali is quite justifiable, in order to make the soap more soluble; they do not consider that the various salts contained in many waters form insoluble compounds with the fatty acids of the soap, while an excess of some sal soda would be more advantageous. The composition of the different kinds of soap, by various manufacturers, are given in the following tables:

HARD SOAPS.

NAME.	Fatty Acids.	Fat and Rosin.	Dry Soda.	Dry Potassa.	Salt. (Na. Cl.)	Lime and insoluble residue.	Water.
American Curd Soap,	67.5	....	7.7	....	....	....	24.2
Holt's Yellow Soap,	....	74.	7,08	....	....	....	18.92
American Soap Company's Soap,	....	35.	5.	....	....	40.	20.
Colgate's Yellow Soap,	....	64.	7.29	....	....	....	28.71
" " "	....	56.2	9.	....	3.8		31.
"Nonpareil" Soap,	....	36.2	5.2	....	5.25		51.9
Beatty's Soap, (patent,)	....	37.	5.5	....	0.5		52.
Butterfield's Soap,	....	32.5*	9.2	....	1.7	2.	55.
German Curd Soap, prepared from potashes after having been kept several years,	81.25	....	8.55	1.77	....	....	8.4
White Tallow Soap, (Leipsic,)	76.3	....	8.8		....	....	14.7
" " "	50.	....	9.4		....	....	29.8
" " "	45.	....	9.8		....	....	38.
Marseilles Soap,	67.16	....	7.82	....	1.08	....	23.94
" "	68.01	....	7.25	....	1.33	....	23.41
" "	66.99	....	7.8	....	4.	....	21.21
French White Soap,	50.2	....	4.6	....	....	....	45.2
" Marbled Soap,	64.	....	6.	....	....	....	30.
White London Toilet Soap,	75.	....	9.	....	....	....	16.

* 10.5 Rosin and 22 Fatty Acids.

HARD SOAPS—*Continued.*

Name.	Fatty Acids.	Fat and Rosin.	Dry Soda.	Dry Potassa.	Salt. (Na. Cl.)	Lime and insoluble residue.	Water.
Poppy Oil Soap,	76.	....	7.	....	....	....	17.
Glasgow Brown Resin Soap,	....	70.	6.5	....	....	....	23.5
Glasgow White Soap,	60.	....	6.4	....	....	....	33.6
Manchester Palm Oil Soap,	56.6	....	7.2	....	....	....	36.
London Curd Soap,	52.	....	6.	....	....	....	42.
London Marine Soap,	22.	....	4.5	....	....	....	73.5
SOFT SOAPS.							
French Fulling Soap,	62.	....	....	11.5	....	....	26.5
Savon mou ordinaire,	42.8	....	....	9.1	....	....	48.
Savon vert,	44.	....	....	9.5	....	....	46.5
Belgian Green Soap,	36.	....	....	7.	....	....	57.
Scotch Rape-Oil Soap,	51.66	....	....	10.	....	....	38.33
Gallipoli Soft Soap,	48.	....	....	10.	....	....	42.
London Soft Soap,	45.	....	....	8.5	....	....	46.5
Manchester Soft Soap,	42.	....	....	8.25	....	....	47.
" "	37.5	....	....	8.81	....	....	44.
" "	36.75	....	....	9.57	....	....	47.75

To Determine the Amount of Water of a Commercial Soap.

Take 80 grains of the respective soaps, and put them in a water-bath, and add a saturated solution of nitre, and heat both to the boiling point; keep boiling for two to three hours, and add more water, if some should be evaporated during the boiling; note the weight, and keep for two hours more heated; if not diminished after that time, it proves that all the water is expelled. If the original weight of the soap was 80 grains, and after drying was but 67 grains, it would make it equal to 16¼ per cent.

To Determine the Amount of Fat.

By decomposing the soap by an acid, the fat is easily found. By putting 80 grains in a porcelain dish, and adding 20 to 30 times as much in weight of oil of vitriol, diluted 12 times with water, and heating the whole over a lamp, until the fat is floating on the top. If 60 grains remain, deduct 3¼ for tallow, which is equal to 88.05 grains, and 80 grains soap would contain 72.8 per cent.

Rosin is detected by ascertaining the weight left undissolved after the alcohol has taken up all the fat, which is, however, a very uncertain test. Other processes have been proposed, by means of strong hydrochloric acid, which appears to be more reliable.

Free alkali may be easily ascertained if it exists in soap.

The following substances are used for filling up the

soap, some of which may be advantageously employed, and some serve as adulterations :

Group I.	Group II.		Group III.	
Water.	*Earthy Matters and Salts.* Soluble and Insoluble in Water.		*Organic Matters.* Soluble and Insoluble in Water.	
	Soluble.	Insoluble.	Soluble.	Insoluble.
	Chloride of Sodium.	*Soluble in Hydrochloric Acid.*	Sugar.	Free Rosin.
	Soda.	MAGNESIA.	Starch.†	Free Fat.
	Glauber Salt.	LIME.	Dextrin.	
	Borax.	CHALK.	Glue.	
	Soluble Glass.	BONE ASHES.		
	Carbonate of Ammonia	PIPE CLAY.		
	Alum.	*Not Soluble in Hydrochloric Acid.*		
	Acetate of Lead.	SULPHATE OF BARYTES.		
		SAND.*		

The object of the introduction of soluble glass in the manufacture of soap, or as a substitute, if economy is at stake, may be exemplified by the following remarks : The treatment of lyes alone, with wool or silk, prove the superiority of the soluble glass, as it removes but externally the adhering dirt, without any injurious effect. The slippery and adhesive consistency of soluble glass act likewise beneficial in the easy washings, and rinsings with much water the adhering impurities.

There are many advantages in its applications on

* An admixture of sand cannot be regarded as fraud, if the soap is *sold* as *sand soap*.

† We do not know if starch has any cleansing qualities ; it is so stated in a report on the different uses of the potato, published in 1827 by the two French chemists, Payen and Chevalier, but we doubt it.

wool, silk, cotton and leather; it is stronger than common soap, requires a less quantity, and either hard, soft, cold or lukewarm water may be employed.

The labor and saving of fuel is an advantageous economy; it preserves also many colors, which are not fast, much better than common soap; it resists, in fact, almost all colors. From one to four pounds liquid glass is sufficient for 100 pounds of water. As that used for wool is quite sufficient for a menstruum, it is employed quite extensively in Europe for washing and fulling of wool, and it has been used long before the soluble glass was known, by dissolving flints in caustic lye prepared from wood ashes.

The Prussian Government has found it advisable for the introduction of the soluble glass in the military and other royal institutions and prisons, and also for the paper manufacturers, and their extensive linen establishments; and instituted experiments as to the practicability of a general economical application.

In the cotton mills it has proved a saving of fifty per cent. by substituting it for starch and flour, which was so indispensable for fastening the colors; and in England, thousands of pounds sterling have been economized by its application. In our late war the consumption of the soluble glass in that branch of industry of the United States was very extensive. The soap manufacturer, who formerly did use rosin for an adulteration or admixture, the cost of which was formerly but two dollars, but rose to twenty-five and thirty dollars per barrel of 180 pounds, was obliged to resort to the use of soluble glass in its various forms, either as liquid or jelly.

Rosin is now again more employed than the soluble

glass; not, however, for the reason that it is better as a sophisticator, but because the soap maker has an idea that the soap formed from rosin with fat suited better, and is more time saving. He does not consider all the circumstances; such as the smell and touch produced in the handling or washing with rosin soap, and that the admixture of soluble glass is no adulteration, but an improvement, and that it is as economical as rosin soap.

The Cryolite Soap,

which was introduced in the market, is a rosin soap, to which the powdered cryolite is added by crutching, or it is added right after the saponification has taken place, before it is taken out from the kettle. The writer has seen such a soap, which was quite soft, and could not be made hard, except by adding some adulteration, such as clay or talc, if it is intended to be a saleable soap.

INDEX.